The DEF's of Oxygen Transport to Increase Endurance Performance

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Essential Ingredients of a Successful Athlete

1) Ability to set achievable goals
2) Interaction wih a competent coach
3) Good nutritional habits
4)An effective training plan (improvement)
5) Consistency in training (compounding)
6) Adequate recovery (prevent injury and increase performance)

7) An unflappable mental attitude (I AM good and I'm going to get BETTER!)

Successful endurance runnners are:

--Happy (energized),
--Healthy,
--Hungry (focused), and
--Fit (trained)

Athlete Adaptations to Distance Running

- 1) increased blood volume
- *2) increased # red blood cells which contain hemoglobin – **iron is part of Hb structure***
- 3) increased stored fuel in muscles
- *4) increased O_2 storage capability in muscles **(via myoglobin, which contains iron)***
- *5) increased # enzymes used for complete fuel metabolism **(iron is part of cytochrome enzyme structure)***
- 6) decreased resting pulse
- Shaskey. D.J., Green, G.A. Sports haematology, Sports Medicine 29: 27-38, 2002.

Importance of Iron in Distance Running

- Hypothesis: inadequate body iron reserves compromise the magnitude of adaptation to the training process
- This limits the quantity and quality of high-level endurance work output
- Thus, it isn't just doing the training that builds fitness, rather, it's adapting to the training stimulus by "building a bigger engine" This engine requires iron!!
- Schumacher, Y.O., Schmid, A., Grathwohl, D., Bultermann, D., Berg, A. Hematological indices and iron status in athletes of various sports and performances. MSSE 34, 869-875, 2002.

Lowered Hb Can Impair Aerobic Performance

- Example (Γ): ↓ Hemoglobin from 16 to 15 gm/dl
- O_2 content decreases from 21.09 to 19.79 ml/dl – this is a (1.3/21.09 x 100) = 6.2% ↓
- Example (Ε): ↓ Hemoglobin from 14 to 13 gm/dl
- O_2 content decreases from 18.49 to 17.19 ml/dl – this is a (1.3/18.49 x 100) = 7.0% ↓
- A ↓ in Hemoglobin from 14 to 13 gm/dl will ↓ VO_2-max by ~ 3%. If VO_2-max ↓ from 68 to 66 ml/kg/min, this can slow marathon pace from 2:26:26 to 2:30:36
- Buick, F.S., Gledhill, N., Froese, A.B. Spriet, L., Meyers,E.C. Effect of induced erythrocythemia on aerobic work capacity. Journal of Applied Physiology 48: 636-642, 1980.

A 27:30 10,000 meter run would be slowed by 49.5 seconds.

A 13:20 5,000m run would be slowed by 24 seconds, etc.

Possible Mechanisms of Iron Deficiency/Depletion in Endurance Runners

- Decreased dietary intake (moreso in women than men)**
- Decreased GI iron absorption**
- Increased sweat losses
- Loss of myoglobin iron (rhabdomyolysis)
- Increased gastrointestinal loss (ulcers, hypoxia)
- Increased menstrual loss (women)**
- Loss of hemoglobin iron from hemolysis**

- **=greatest importance

If there is one single atom that is most crucial for an endurance athlete's success, it is iron

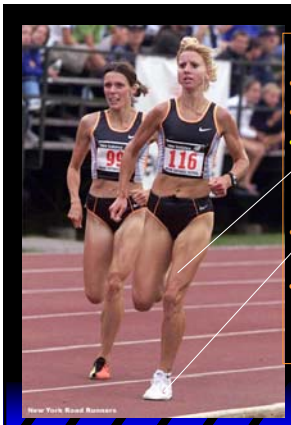
Functional Monitoring of Iron Status

HEMOGLOBIN (Hb)

- A protein normally occupying ~ 1/3 of red blood cells (MCHC)
- 98.5% of the blood's O_2 is chemically bound to Hb for transport to metabolizing tissues
- As Hb changes, so does VO_2max – thus, it is not JUST training that affects VO_2max – remember the interaction between good health & good fitness!
- Normal range of Hb for men is 15 to 18 gm/dl; for women 12 to 15 gm/dl

Hematological Aspects of Overuse

- Iron deficiency causes overtraining in many runners
- --- iron is part of the hemoglobin molecular structure
- --- hemoglobin carries 98.5% of blood oxygen
- --- more than half of the enzymes of aerobic metabolism contain iron
- --- thus, a ↓ in iron stores can → a ↓ in aerobic capacity (VO_2max)
- --- excessive impact stress can cause hemolysis due to extravascular compression and intravascular acidosis



HEMOLYSIS IN RUNNERS

- ↑ Blood acidity
- ↑ RBC transit velocity
- Extravascular compression of major working muscles
- ↑ Plantar surface compression at footstrike
- Mean life of rbc in runners = 80 days (versus 120 days in sedentaries)

Artist's Conception of Capillaries in Skeletal Muscle

Iron Inadequacy is a Common Problem

- Occurs in 10% to 25% of the normal US population
- Caused primarily by increased refining & processing of food, PLUS a decreased use of cast-iron cooking utensils – we are a Teflonized society!
- Deficiency of iron is more common than that of any other nutrient – elite runners (esp. women) tend not to eat red meat

Iron Depletion vs. Iron Deficiency

- IRON DEPLETION: subnormal body iron stores, most easily seen as decreased serum ferritin levels
- IRON DEFICIENCY: inadequate iron supplies to permit normal erythrocyte and hemoglobin levels in the blood

Dietary Sources of Iron

- **Heme iron** – exists in meat &, liver, and is quite easily absorbable
- **Nonheme iron** – found in other foods:
- Egg yolks, dried fruits, baked beans & molasses, soybeans, spinach, broccoli, lima beans, sweet potatoes, brussels sprouts
- Nonheme iron is poorly absorbable

Absorption of Iron into the Body

- Absorbable iron is in the ferrous state (Fe^{++})
- **Heme iron** does exist in the Fe^{++} state and thus absorbs easily
- Vegetable sources of iron are typically in the ferric state (Fe^{+++}), and thus must be acidified for conversion to Fe^{++}
- Enhancers of $Fe^{+++} \rightarrow Fe^{++}$: vitamin C, citric acid, OJ, apple sauce, etc.
- Inhibitors of $Fe^{+++} \rightarrow Fe^{++}$: phosphoprotein (egg yolks), bran fiber, polyphenols (coffee, tea)

Functional Monitoring of Iron Status

FERRITIN

- A protein which chemically binds iron; found in practically all living cells
- Because it also circulates in the plasma, plasma ferritin levels mirror total iron stores
- Ferritin is the body's most accurate indicator of iron stores
- < 20 ng/ml ⇒ inadequate bone marrow iron
- 20 - 30 ng/ml ⇒ sizable iron depletion
- > 50 ng/ml ⇒ OK
- Beware of hemochromatosis (iron storage disease), which has same symptoms as anemia

Iron Supplementation in Distance Runners

- Distance running is an aerobic event, requiring adequate transportable O2 in the bloodstream; Hb mediates this transport
- More than 50% of the enzymes for aerobic metabolism are iron-containing; part of the 'getting fit' process thus involves producing more mitochondrial enzymes for aerobic metabolism
- Distance runners may not get adequate dietary intake of iron, making iron supplementation potentially worthwhile
- Since iron absorption occurs in the first part of the small intestine, breakdown of iron-containing pills often does not occur quick enough to ensure absorption

Iron Supplementation in Distance Runners

- Liquid iron is suggested as the optimal means for non-dietary iron intake
- Our experience with 25 years of working with distance runners suggests that 1 mg elemental iron per kg body weight per day when ferritin levels are below 30 ng/ml serves to maintain ferritin levels at or above 30 ng/ml
- Example: a 50 kg woman (110 lb) needs 50 mg iron; a 60 kg man (132 lb) needs 60 mg
- One tsp liquid iron has 45 mg elemental iron; the woman could take 1 tsp. per day, the man 1 ½ tsp. per day, with orange juice
- Beware of hemochromatosis (iron storage disease), which has the same symptoms as anemia

Functional Monitoring of Iron Status

HAPTOGLOBIN (Hp)

- A plasma protein, produced by the liver, which chemically bids to hemoglobin released into plasma when red blood cells rupture (hemolysis) due to impact stress or extravascular compression
- The resulting Hb:Hp complex gets transported to the liver, where the hemoglobin is metabolized and the iron conserved
- Excessive hemolysis ⇒insufficient Hp ⇒spilling of hemoglobin into the urine ⇒ potential iron loss
- > 50 mg/dl ⇒ adequate Hp; < 25 ⇒ likely iron loss

Functional Monitoring of Iron Status

URINE HEMOSIDERIN (Hs)

- Kidney tubules reabsorb filtered hemoglobin in an attempt to prevent its loss
- Metabolism converts hemoglobin to hemosiderin
- Normal kidney cell growth & replacement causes cell sloughing, which forms part of urine sediment
- Centifugation of the urine specimen, and staining the sediment reveals presence of hemosiderin (Hs)
- A positive hemosiderin test ⇒ sizable hemolysis from footstrikes or extravascular compression

Functional Monitoring of Iron Status

RETICULOCYTES

- These are 1-2-day-old red blood cells
- Their elevation implies an increased release of young red blood cells from bone marrow due to a recent loss (as with hemolysis)
- If elevated to > 75,000 per liter, this suggests a vigorous response to a recent red cell loss, but also implies adequate iron stores
- A low reticulocyte count coupled to low Hb suggests low iron stores or iron loss (check ferritin, Hp, Hs)

SUMMARY: What Are The DEF's?

D = Dissolved oxygen; only 1.5% of the total in the blood – inadequate – we need oxygen BOUND to hemoglobin

E =- erythropoietin – the protein hormone from the kidney that stimulates hemoglobin production, which transports 98.5 of the blood oxygen

F = ferritin – carries iron for use in hemoglobin production