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Anaemia in athletes

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It is well known that the efficiency of oxygen supply for the organism is of particular importance for physical performance, especially in endurance disciplines. The oxygen supply for the organism is influenced mainly by the oxygen carrying capacity of blood. This parameter depends primarily on the concentration of haemoglobin and the number of circulating red blood cells. A highly significant positive correlation was observed between haemoglobin concentration and physical performance measured as the maximal oxygen consumption (VO2 Max) (3, 42). Similar correlation was observed between VO2 Max and the circulation blood volume (42).

Not surprisingly; a considerable decrease in maximal oxygen consumption was found following phlebotomy-induced, controlled blood loss. This was accompanied by lowered tolerance to physical exercise. After reinfusion of red blood cells a reverse effect was discovered in both : increase in VO2 Max and in duration of physical work until exhaustion. It has also been found that increased performance persists during four or more weeks after "blood doping" as this procedure has been termed (3, 16).O

On the other hand it is well known that anaemia leads to a decrease in both maximum oxygen consumption and physical work capacity. Even a slight decrease in haemoglobin concentration - by 1 to 2 g/dl - could lead to a decrease in work tolerance even by 20% (45). Of course, the greater severity of anaemia, the more pronounced decrease in work capacity.

In the light of these findings it is extremely intriguing that many authors reported a decrease in the haematological indices such as haemoglobin concentration, red blood cells count and haematocrit after a single physical effort as well as during continued training periods (38). It has also been found that under resting conditions the morphological parameters of the erythrocyte system are lower in some top-class athletes, particularly those performing in endurance disciplines, for instance cycling or log distance running (4, 6, 36). Please call attention to the fact that in these disciplines the amount of oxygen supplied to the working muscles is of an utmost importance for the production of energy and, in consequence, for the performance and the sports result.

Most interestingly, for more than ten years many reports have been published on anaemia occurring in top-athletes, even among the members of Olympic teams (4, 6, 12, 36).

This kind of anaemia has been termed sports anaemia, athletes anaemia, post-exercise anaemia, runner's anaemia or swimmer's anaemia, in order to emphasize its character (14, 33, 46).

The term "sports anaemia" was used for the first time by Yoshimura 1959 (46). Till now, however, this phenomenon has not been fully recognized. Moreover there are many misunderstandings around this subject. It has been also proposed that "sports anaemia", as an unique clinical entity, does not exist at all, and the term "sports anaemia" might be inappropriate and misleading, thus should be avoided (15, 43).

Among many possible causes which may bring about development of anaemia in athletes, three are the most commonly cited:
1) post-training plasma expansion;
2) haemolysis intensified during physical effort;
3) iron deficiency.

Some authors also emphasize the disturbances in erythropoiesis due to heavy physical training.

1. Blood plasma volume expansion

Even a single intense physical effort leads to deep changes in plasma volume, such as a transitory decrease of PV by about 10 - 20% immediately after prolonged heavy exercise and a significant increase by 16 - 17% during the next hours of recovery (10, 21, 30, 41).

Physical training leads to a fixation of that phenomenon. Increase in plasma volume, even by 10 -33%, with simultaneous rise in blood volume by 10 - 12% was observed during successive days training (13, 18, 21, 25, 29). The expansion of plasma volume was accompanied by a decrease in haemoglobin concentration, haematocrit and erythrocyte count due to haemodilution effect (29). It is recognized as an delusional anaemia.

Many authors believe that the training-induced rise in plasma volume is a beneficial adaptation that improves endurance capacity and resistance to fatigue (8, 13, 15, 17, 18, 25).

This kind of anaemia is also called false or pseudoanaemia in athletes (15).

2. Haemolysis during physical exercise

The phenomenon of intensified destruction of erythrocytes during physical efforts and haemoglobinuria following severe exercises has been known for over a century. In 1881 Fleischer described for the first time, haemoglobinuria after long-lasting, exhaustive marches. This was the birth of the traditionally accepted term "march haemoglobinuria" (9).

Since then, haemoglobinuria was described many times in young, healthy men after prolonged, exhaustive runs and march-runs and attributed to an excessive lordosis which could deteriorate renal function. It was also connected with a mechanical damage of red blood cells in the blood vessels of the feet, especially on a hard surface (9, 10, 46). Intensified destruction of erythrocytes and haemoglobinuria was also described after karate training and called "traumatic haemoglobinuria"(37).

However, it has been shown, that intensified intravascular haemolysis and haemoglobinuria may also happen in such disciplines as weight lifting, swimming and rowing where there is no traumatisation of the blood vessels of the at all(14, 24, 32, 33). Hence it seems that emphasizing the mechanical damage of erythrocytes as the only cause of exercise-induced haemolysis is an oversimplification.

According the literature, there are other factors besides mechanical damage which can intensify red blood cell destruction during intense physical effort. They are listed below and thoroughly reviewed by Balaban (1), Miller (26), Smith (35) and Szygula (38):

1. RED BLOOD CELL AGE and aging-associated changes in erythrocyte metabolism and membrane;
2. SOME BIOPHYSICAL AND BIOMECHANICAL CHANGES IN BLOOD, such as: haemoconcentration of blood, acidosis, elevation of body temperature, hypoglycaemia and elevation of the level of blood cathecholamines;
3. CHANGES IN RED BLOOD CELL SHAPE observed after heavy prolonged exercise;
4. Intensified generation of FREE RADICALS and increased lipid peroxidation of the membrane of red blood cells.

Although all above factors may not directly cause erythrocyte destruction, however they can facilitate haemolysis, especially of the older erythrocytes.
A pronounced destruction of red blood cells was observed mainly at the beginning of the training period (29). Intravascular haemolysis,however, was also described in well trained athletes (24, 44).

Therefore it seems very likely, that haemolysis intensified during heavy physical training may possible cause of the true anaemia in sportsmen.

3. Iron deficiency in sportsmen

The iron deficiency is the most frequent cause of anaemia in many populations. It is also the most common cause of true anaemia in sportsmen. There are several studies showing significant prevalence of iron deficiency with and without anaemia in endurance athletes, particularly female and young athletes (1, 5, 7, 23, 27).

There are many possible causes leading to the iron deficiency in sportsmen. They are:

1. Insufficient content of iron in diet;
2. Reduced intestinal iron absorption;
3. Increased iron requirement particularly in young athletes and in those just beginning an intensive physical training;
4. Increased loss of iron.

There are several possible ways of iron loss from the organism of athletes: haemoglobinuria and myoglobinuria, haematuria and the loss of iron with sweat as well as minute bleedings into the digestive tract (1, 5, 7, 23, 26, 27, 34).

On the basis of the listed evidence, it can be concluded that iron deficiency is the most important and real cause of true anaemia in sportsmen.

4. Disturbances in erythropoiesis

As I said at the beginning of the lecture, some authors believe that disturbances in erythropoiesis due to heavy physical training may also lead to anaemia in athletes.

These hypothesis widely accepted for many years has postulated that a transient hypoxia during a strenuous exercise stimulates erythropoietic (EPO) biosynthesis by the kidneys (20, 38). Indeed, a remarkable increase in plasma erythropoietic activity was observed immediately after long lasting efforts (11, 40).However when using very sensitive radio immunoassays, elevated levels of serum EPO were not found after exercise (2, 28, 31). Moreover there is a suggestion that both short maximal and long lasting submaximal exercises might even suppress EPO biosynthesis and deteriorate erythropoiesis (28).

There are some possible reasons for the suppression of erythropoiesis in athletes (38, 39).

1. EPO biosynthesis might be suppressed by metabolic acidosis and haemoconcentration observed during physical exercise. Rejuvenation of the circulation erythrocytes (training-induced adaptive changes) and better oxygen supply to tissues as well as to the oxygen sensor in the kidneys may also suppress EPO synthesis;
2. Iron deficiency and lowering of iron stores in bone marrow as well as shift of iron from bone marrow to hepatocytes, as a consequence of intense exertional haemolysis;
3. Hypocellularity of the bone marrow;
4. Reduced level of serum testosterone due to overtraining;
5. Changes in lymphocyte subsets: reduced number of T4 lymphocytes and T4/T8 ratio. Since the T4 lymphocytes play an important role in stimulation of the early stages of erythropoiesis, their deficiency or increased fraction of T8 lymphocytes can disturb the process;
6. Abuse of anti-inflammatory and analgesic drugs by athletes may also disturb EPO synthesis as well as cause damage of bone marrow.

As shown above,it seems very likely that heavy physical training can disturb EPO biosynthesis and erythropoiesis and thus leads to anaemia in athletes.

5. Diagnosis and treatment of anaemia in athletes

As it was discussed earlier, the balance of evidence indicates that delusional anaemia is the most frequent form of anaemia in athletes. It should be emphasized that it is not the true anaemia and thus requires no treatment with iron containing medication. It must be however pointed out that true anaemia dan also develop in athletes and any abnormality in haematological indices have to be accurately investigated.

The following are the haematological criteria pointing to the **delusional anaemia**:

haemoglobin, levels between 13 - 14 g/dl for men and 11 - 12 g/dl for women as well as serum ferritin level of no less than 290 mg/ml and 12 ng/ml respectively.

As the criteria for **true iron deficiency anaemia** we can accept the levels of haemoglobin lower than 13 g/dl in men and 11 g/dl in women and serum ferritin levels lower than those mentioned above.

Sometimes however it is not easy to discriminate between delusional pseudoanaemia and true mild iron deficiency anaemia. Although the level of serum ferritin seems to be a very sensitive index for assessing iron reserve in the body, it has been proposed, that more strict diagnostic criteria should be used (43).

Iron deficiency should thus be recognised on the basis of at least two of the following parameters:

serum ferritin (SF) < 12 ng/ml
free erythrocyte protoporphyrin > 70 μg/dl of RBC
transferrin saturation (TS) < 16%

True iron deficiency anaemia can be recognized when in addition to the above, the blood haemoglobin (Hb) concentration is lower than 11 g/dl in women and 13 g/dl in men.

When the delusional anaemia is confirmed there is no need for iron supplements.

When iron deficiency is suspected, first of all a careful examination should be done. Iron deficiency might be the very early signal of a serious illness.

Because iron deficiency is the most common cause of true anaemia, some sportsmen and coaches believe that superalimentation of iron is necessary. However, it should be emphasize that iron deficiency could be prevented not by pharmalogical supplementation but by recommending a suitable diet.

If there is no improvement after applying the suggested changes in diet, or when a severe reduction in iron stores is recognized (SF< 12ng/ml) the oral iron therapy should start immediately. Ferrous sulfate is recommended in doses 325 mg three times a day for 1 or 2 months. However a long-term treatment or excessive doses of iron should be avoided. Iron overload may lead to such toxic effects as disturbances in the balance of other metals (mainly zinc) and lesions in internal organs.

6. Conclusions

6.1 Delusional anaemia due to the training-induced volume expansion is the most frequent form of anaemia in athletes. It is not true anaemia but to recognize athletes' pseudoanaemia other reasons of anaemia ought to be excluded.

6.2 Though the most common reason for true anaemia is iron deficiency, it is not recommended to use iron supplementation as a preventive treatment.

6.3 Iron supplementation should be used only if iron stores are considerable reduced.

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