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Metabolic diseases: the latest findings in sports
Actualităţi ale bolilor metabolice în sport

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Abstract

Intense exercise determines body and metabolic adaptations considered beneficial to health. Practicing an intense training program and ongoing performance or participation in competitions can induce changes in serum laboratory parameters and cause effects on the body, health and social life. So, when they reach the end of their careers, most athletes can have weight problems. The cause is the inadequacy of the number of calories required for daily and physical effort. Staying on the same diet during the cessation of exercise training camps will eventually lead to the appearance of weight imbalances. Obesity is a problem not only after the age of retirement. Recent studies show an increasing prevalence of obesity among active athletes. In this category of patients, the calculation of abdominal circumference and body fat percentage, not of BMI, should be considered. The presence of obesity is also associated with metabolic syndrome or insulin resistance. Diabetes is another chronic condition that can affect athletes. If blood glucose levels are monitored incorrectly during periods of exercise, athletes with diabetes can suffer various endocrine emergencies (hypoglycemia, hyperglycemia and diabetic ketoacidosis). The greatest risk occurs in patients with type 1 diabetes by developing hypoglycemia or ketoacidosis. In type 2 diabetes, it is less pronounced, especially in those treated only with diet. To achieve performance levels, these patients should coordinate their carbohydrate intake and insulin administration to avoid complications. Glycemic control can be achieved by reducing insulin dosage by 50-80% depending on the type, duration, intensity and familiarity of exercise. Sport activity induces a lipid profile superior to that of sedentary patients, especially on HDL. Unfortunately, there are few studies that clarify the differentiation of the benefit of certain sports.

Key words: sports medicine, intense exercise, obesity, diabetes, hypoglycemia.

Rezumat

Exerciţiul fizic intens determină adaptări ale organismului şi ale metabolismului considerate benefice pentru sănătate. Practicarea unui program de formare intens şi continuu sau participarea la competiţii de performanţă poate induce modificări ale concentraţiilor serice ale unor parametri de laborator şi poate determina efecte asupra organismului, stării de sănătate şi vieţii sociale. Astfel, atunci când ajung la capătul carierei, majoritatea sportivilor pot avea probleme de greutate. Cauza acesteia este neadaptarea numărului de calorii necesare zilnic cu efortul fizic depus. Rămânerea la acelaşi regim alimentar din timpul cantonamentelor şi sistarea exerciţiului fizic poate duce la apariţia dezechilibrelor de greutate. Obezitatea nu este o problemă doar după vârsta retragerii. Studii recente arată o prevalenţă în creştere a obezităţii şi printre sportivii activi. De menţionat faptul că la această categorie de pacienţi nu trebuie luată în considerare calcularea IMC, ci a circumferinţei abdominale sau a procentului de grăsime din corp. Prezenţa obezităţii a fost, de asemenea, asociată cu cea a sindromului metabolic sau a insulinorezistenţei. Diabetul zaharat este o altă afecţiune cronică ce poate afecta sportivii. În cazul în care nivelurile de glucoză din sânge sunt monitorizate incorect în timpul perioadelor de exerciţiu, atleţii cu diabet zaharat pot suferi diverse urgenţe endocrine (hipoglicemie, hiperglicemie, cetoacidoză diabetică). Riscul cel mai mare apare la pacienţii cu diabet zaharat de tip 1 prin dezvoltarea hipoglicemiei sau a cetoacidozei. La diabeticii de tip 2 acesta este mai puţin pronunţat, în special la cei trataţi doar prin dietă. Pentru a atinge nivele de performanţă, aceştia trebuie să îşi coordoneze ingestia de carbohidraţi şi doza de insulină pentru a evita apariţia complicaţiilor. Un control bun al glicemiei se poate obţine prin reducerea cu 50-80% a dozei de insulină în funcţie de tipul, durata, intensitatea şi familiaritatea exerciţiului. Activitatea sportivă induce un profil lipidic superior faţă de cel a pacienţilor sedentari, în special cu privire la nivelurile de HDL. Există însă puţine studii care să diferenţieze clar beneficiul unei anumite discipline sportive.

Cuvinte cheie: medicina sportivă, exerciţiu fizic, obezitate, diabet zaharat, sindrom metabolic.

Introduction

Metabolism is an ongoing process through which the body gets energy from food. A metabolic disorder occurs whenever there are abnormal chemical reactions in the body.

It is now common knowledge that sport activity, practiced either as a professional or as a leisure activity, is a factor of harmonization and optimization of health. Practicing an intensive training program and participating in competitions causes changes in serum laboratory parameters and has effects on the body, health status and social life.

The benefits of regular exercise for healthy individuals are well established, and such benefits also exist in the case

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of athletes suffering from metabolic diseases. Nevertheless, there are few studies that challenge this relationship. One explanation may be that athletes constantly and carefully monitor their physical and chemical parameters, and depending on their values, they know when they can safely practice physical activities. The psychological impact of chronic diseases on life can also be improved. Practicing physical exercise reduces anxiety and increases self-confidence, which leads to an easier acceptance of the disease (Farrell, 2003).

Ending sports career and weight problems

As a physically active population group, athletes are usually perceived by the public as healthy and strong. Thus, they are not considered to be a category of individuals at risk for developing eating disorders. However, this misconception is why food behavior problems may be overlooked in athletes.

The end of a sports career, which is an important part of an athlete's identity and life, may be a difficult transition. When athletes retire from their professional career due to injury, retirement is even more difficult and has a serious impact on career, may cause income loss and negatively affect physical recovery. Research on the impact of athletes' retirement is limited. The results show that most often this is a stressful, challenging and demanding process (Hurley, 2014).

Athletes often face the problem of maintaining body weight after retirement from the sport. In addition to the aging factor, there are several reasons that cause weight gain after retirement. The lack of support from the National Sport Authorities may also contribute to mental and physical degradation (Suptu, 2012).

The first reason is the inadequacy between food behavior and the new lifestyle. The first year after withdrawal usually mostly affects the athlete's health. Weight gain occurs either through ingestion of previously prohibited food or the disappearance of the need to stay fit. Over time, muscles diminish and fat begins to grow.

The second major problem faced by athletes after retirement is the psychological need to relax mentally and physically, as they are no longer living by a strict schedule (both diet and exercise). Training camp fatigue and the rigor of a daily program leave a gap in the life of former athletes after retirement. Fortunately, such athletic breaks are not very long, as athletes become aware of the health problems which may arise. After a while, they try to adopt an exercise program and a diet according to their new lifestyle. Still, for athletes, returning to the gym is substantially more difficult than it is for untrained persons. Apparently, marital status plays an important role, as research shows that retired single athletes are more motivated to stay in shape than married people.

Cardiovascular risk in athletes

Cardiovascular disease is the first cause of mortality and morbidity in developed countries. The main cause of this disease is atherosclerosis, which is accelerated by exposure to certain risk factors.

Risk factors associated with cardiovascular disease include age, heredity, male sex, smoking, increased serum cholesterol, physical inactivity, metabolic syndrome, or just the presence of obesity and diabetes.

Those who practice high performance sports are perceived as healthy individuals due to their young age and intense daily physical activity. However, there are few studies that evaluate the correlation between the type of physical activity and the presence of cardiovascular risk in athletes. It has been noted that regular physical exercise does not necessarily prevent the development of obesity in athletes. The sports in which obese athletes are most frequently found are American football, golf, baseball, sumo and boxing (Borchers et al., 2009). Like in the case of the general public, for this particular category, the following factors should be examined: blood pressure (BP), body mass index (BMI), waist circumference, hip circumference, blood lipids, blood glucose (Muñoz et al., 2009). A more specific method than calculating the BMI is measuring abdominal circumference or the percentage of body fat (Borchers et al., 2009).

Trying to assess cardiovascular risk in young college athletes, Muñoz L. et al. noted in 2009 that of 135 athletes, more than a quarter were overweight, a fifth were prehypertensive, and a quarter had lower HDL levels than the recommended limit. This research shows that athletes are also prone to a high cardiac risk after retirement, when they cease daily physical activity.

Depending on the sport, Helzberg et al. (2010) noted that former American football players in the National Football League had an increased risk of cardiovascular disease and premature death compared to baseball players. These complications arose because of a higher prevalence of obesity, high serum cholesterol, left ventricular and atrial hypertrophy and metabolic syndrome in linemen compared to other types of players.

Further research is needed to assess cardiovascular risk in active athletes, in relation to physical activity corresponding to each sport, especially since there are many questions regarding cardiovascular risks in athletes (Borchers et al., 2009).

Endocrine changes in athletes

Practicing sports is recommended to anyone, especially if they suffer from diabetes (either type 1 or 2). Normal insulin production and action are essential for proper metabolic response to exercise and so, in this special category of athletes, complications can occur either because of the total lack of insulin secretion (type 1 diabetes) or because of deficient glucose absorption (type 2 diabetes).

In healthy persons, metabolic response to exercise consists of decreased insulin secretion by the pancreas. It is known that skeletal muscle has an important role in glucose uptake (especially during exercise) and that insulin is the main stimulator of glucose uptake by cells. Muscle contraction during exercise stimulates glucose uptake in muscle, even when insulin secretion is low. Thus, this decrease in insulin release during exercise has the role to prevent hypoglycemia (Farrell, 2003).

However, some sports pose greater challenges to diabetic athletes than to those without this disease:

- Unforeseen events during competitions may disrupt the plan of athletes regarding insulin dosage or carbohydrate intake, which lowers performance.

- In winter sports, diabetics should consider the fact that insulin in the pump or that carried for injections may freeze.
- The insulin pump may be damaged in many contact sports (football, rugby, hockey, wrestling, etc.)
- To prevent potential damage to the retina, diabetic athletes practicing boxing, judo or karate should be closely monitored.

To avoid unpleasant situations, there are several steps to be taken before training:

a) Measurement of serum glucose concentration

- If glycemia is <5 mmol/l (90 mg/dl), it will be necessary to supplement carbohydrate intake.
- If glycemia is 5-15 mmol/l (90-270 mg/dl), carbohydrate supplementation is not mandatory.
- If glycemia is >15 mmol/l (270 mg/dl), it is recommended to postpone exercise and measure ketonuria.
- If ketone bodies are negative, exercise can be performed, and carbohydrate supplementation is not necessary.
- If ketone bodies are positive, it is recommended to administer insulin and delay exercise until they become negative.

b) Adequate determination of carbohydrate intake

- Before exercise, the intensity, duration and energy needs for sport can be estimated by consulting standard tables.
- Carbohydrate requirements can be assessed based on the fact that each gram of carbohydrate is equivalent to four calories.
- Diabetics should eat a meal 1-3 hours before training. This snack should contain about 15 grams of carbohydrates for 30 minutes of moderate intensity exercise.
- Drinks that contain simple carbohydrates and electrolytes are excellent to prevent hypoglycemia and plasma volume depletion during exercise.

c) Proper administration of insulin doses

- Insulin must be injected or the insulin pump must be adjusted approximately 1 hour before training.
- The dose should be reduced so that the largest increase in circulating insulin does not occur during training.
- It is recommended to avoid administration in the arm or leg to be involved in exercise (Farrell, 2003).

Daily or competition requirements may predispose athletes with diabetes mellitus to dangerous complications. A correct understanding of glucose metabolism during exercise, adequate nutrition, blood glucose control, medication and proper treatment of complications are the main aspects to be considered in the case of an athlete with diabetes. These patients must be followed up and treated by an expert team consisting of a physician, a trainer and a nutritionist (Macknight et al., 2009).

For example, hyperglycemia is an endocrine emergency that may occur in diabetic athletes. Drinking water in excess during intense exercise and sodium loss through sweating can dilute the blood sodium content. Thus, exertional hyponatremia may cause hyperglycemia (Chansky et al., 2009).

In healthy athletes and in athletes with type 2 diabetes, a decrease in normal serum insulin occurs during exercise, which allows carbohydrates and fats to be mobilized and used by muscles. In those with type 1 diabetes, this phenomenon does not occur because they cannot produce and therefore cannot reduce insulin levels. Athletes with type 1 diabetes mellitus have an increased risk of developing ketoacidosis or hypoglycemia (including that induced by the increased use of glucose during intense training). In type 2 diabetics, risk is less pronounced, especially in those treated only by diet (Kirk, 2009; Prager et al., 1993).

Glycosylated hemoglobin (HbA1c) is an indicator that determines long-term glycemic control. Its value is decreased in type 2 diabetics who practice sports regularly, also reducing the development of complications. Unfortunately, even if other metabolic markers can be improved by exercise, in patients with type 1 diabetes, the correlation of glycemic control with the HbA1c value is not possible (Farrell, 2003).

Lipid profile in athletes

Physical exercise is associated with a decreased risk of cardiovascular disease; this effect is due to a reduction of body fat and to an alteration of its distribution, as well as to changes in the lipids and enzymes involved. These changes are visible in both athletes and sedentary people (Cambri et al., 2006).

Lipoproteins are hydrophilic associations of proteins and lipids. Their main role is to transport lipids in tissues and blood. The outer envelope of lipoproteins is composed of a layer of phospholipids, containing free cholesterol and apolipoproteins. Inside, these contain triglycerides, cholesterol esters or fat-soluble vitamins.

The lipoprotein classes are the following (Table I):

Table I

Lipoprotein classes (1).

Indicator	CM	VLDL	LDL	HDL
Density (g/ml)	< 0.94	0.94-1.006	1.006-1.063	1.063-1.210
Diameter	6000-2000	600	250	70-120
Total lipids (wt %)	99	91	80	44
Triglycerides	85	55	10	6
Cholesterol esters	3	18	50	40
Cholesterol	2	7	11	7
Phospholipids	8	20	29	46

The apoprotein AI system comprises the class of HDL lipoproteins that plays a role in reverse cholesterol transport (RCT) and is the main class of lipoproteins with an antiatherogenic effect. Cholesterol released from peripheral tissues returns to the liver using HDL. Particles of phospholipids and apoAI take this cholesterol, and HDL3 particles result. These are converted to HDL2 under the action of LCAT (lecithin-cholesterol acyltransferase, activated by apoAI), which catalyzes the esterification of free cholesterol.

After this transformation, HDL2 can follow three pathways: it can be captured by the liver using SR-B1 (scavenger receptor B1), it may transfer cholesterol esters to LP containing apoprotein B100 (LDL, VLDL, IDL), a transfer catalyzed by CETP (cholesteryl ester transfer protein), or it may be captured by steroid hormone-producing endocrine cells, which present HDL receptors (Rader, 2006).

Dyslipidemia is characterized by an alteration of plasma lipoprotein concentrations, a strong predictor of chronic degenerative diseases. Numerous studies have explored the relationship between blood cholesterol and the occurrence of atherosclerotic disease. There is also evidence that treatment with HMG-CoA reductase inhibitors (statins) for the reduction of serum lipids helps both in the primary and secondary prevention of atherosclerotic disease. Changes in serum lipids related to the primary prevention of atherosclerotic disease are even more important in athletes, especially in those without obvious clinical manifestations.

It is known that the plasma level of high density lipoproteins (HDL) is inversely correlated with the development of cardiovascular risk. HDL has effects on antioxidant, antiinflammatory and antithrombotic activity, and the increase of serum HDL levels reduces the risk of atherosclerosis. The main protein component of HDL is apolipoprotein AI (apoA-I). Its serum level is also higher in trained athletes than in sedentary people. These data confirm the fact that lipid profile can be improved. Furthermore, the serum levels of different fractions can be modified depending on the sport (Lee et al., 2009). The prevalence of hypercholesterolemia (total cholesterol >200 mg/dl), hypertriglyceridemia (triglycerides >150 mg/dl) and low HDL (<45 mg/dl) is lower in athletes than in sedentary subjects. Athletes who practice endurance activities have 40-50% higher serum high density lipoproteins (HDL), 20-30% lower serum triglycerides (TG) and 5-10% lower low molecular weight lipoproteins (LDL) than people who do not practice sport (Reamy et al., 2004).

Exercise has effects not only on circulating HDL and LDL levels, but also on reverse cholesterol transport (RTC). This is a dynamic process that includes several steps, among which the removal of excess cholesterol from peripheral tissues, arterial walls or macrophages, and its delivery to the liver for excretion. Although epidemiological studies consistently show that HDL is inversely correlated with cardiovascular risk, serum HDL level is not an indicator for RTC. Olchawa et al. (2004) studied RCT in endurance-trained athletes compared to a group of physically active people. They found that a higher level of physical fitness was associated with increased HDL formation, indicating an increase in the efficiency of RCT. The reason for the higher HDL concentration in the trained individuals was the enhanced formation of HDL from apoA-I and cellular lipids (Olchawa et al., 2004) (Table II).

Table II

Parameters of lipid metabolism in athletes and normally active subjects (controls).

Parameter	Controls	Athletes	P
VO2 max (mL/min per kg)	38.8± 1.0	53.4 ±1.2	<0.001
BMI (kg/m2)	23.2 ±0.4	23.9 ±0.5	NS
Waist/hip ratio	1.00 ± 0.01	0.98± 0.01	NS
TC (mmol/L)	4.9± 0.1	5.2 ±0.2	NS
LDL (mmol/L)	2.9 ±0.2	3.2 ±0.2	NS
ApoB (mg/dl)	73.4 ±3.0	75.9 ±3.5	NS
TG (mmol/L)	1.1 ± 0.1	0.9 ±0.1	NS
HDL (mmol/L)	1.4 ±0.1	1.7 ±0.1	<0.001
ApoA1(mg/dL)	128 ± 3	145 ±2	<0.001
Prebeta1-HDL	37 ± 3	54 ± 4	<0.001
LCAT mass (µg/ml)	7.0 ±0.3	6.6 ±0.4	NS
LCAT activity (nmol/ml per h)	24.2 ± 1.4	29.8 ±1.2	< 0.005
CETP mass (µg/ml)	1.7± 0.1	2.0± 0.1	NS
CETP activity (nmol/ml per h)	73 ± 2	67± 3	NS
Cholesterol efflux (%)	16.2± 0.3	18.8 ±0.8	< 0.02
Cholesterol efflux per ApoA1 unit	0.13 ± 0.01	0.13± 0.01	NS

Mean ± SEM is shown

N = 25 athletes and 33 controls, except for cholesterol efflux studies when N = 9 athletes and 24 controls.

Various studies have compared serum HDL levels depending on the sport. Lee et al. (2009) studied the serum lipoprotein differences between runners, throwers, wrestlers, weightlifters, and a control group. Of these, runners had the highest antioxidant activity correlated with increased serum HDL levels. Using immunodetection, it was shown that wrestlers and runners had the highest apoA-I level and the lowest apoA-II level in the HDL fraction. In these athletes, electron microscopy also evidenced the largest HDL2 particles.

These results suggest that endurance-trained athletes, namely runners, have the most effective lipid profile, the best lecithin-cholesterol acyltransferase (LCAT) and paraoxonase 1 (PON1) activity, low cholesteryl ester transfer protein (CETP) activity, increased serum apoA-I levels, and the largest HDL2 particles. The results show that the decrease of oxygen reserve during exercise may improve the function and quality of HDL (Lee et al., 2009) (Table III).

As with sedentary patients, in athletes it is preferable to treat dyslipidemia with statins. There are some concerns about the use of this class of drugs in athletes. For instance, the side effects that may occur with this therapeutic class are muscle cramps and pain. Increased levels of creatine

Table III

Serum parameters in athletes and references.

	Age (yr)	BMI (kg-m^2)	TC (mg/dl)	HDL-C (mg/dl)	HDL-C/TC (%)	TG (mg/dl)	LDL (mg/dl)	GOT (U/L)	GPT (U/L)
Running (1) (n = 10)	24 ± 3.9	19.7 ± 1.2a, (3)	149 ± 21a	52 ± 5a	36 ± 6a	56 ± 17a	88 ± 16a	22 ± 4a,b	13 ± 4a
Throwing (2) (n = 10)	20 ± 0.0	27.6 ± 2.5b	142 ± 18a	44 ± 7b	31 ± 6b	79 ± 37a,b	82 ± 17a	25 ± 5a	15 ± 5a
Wrestling (n = 10)	20 ± 0.4	22.9 ± 1.8a	155 ± 23a	58 ± 6a	38 ± 3a	67 ± 18a	84 ± 16a	19 ± 3b	9 ± 2b
Lifting (n = 8)	21 ± 0.5	29.3 ± 3.8b	141 ± 10a	44 ± 13b	31 ± 8b	54 ± 19a	79 ± 6a	29 ± 10a	19 ± 10a
Reference (n = 14)	22 ± 3.5	21.5 ± 2.7a	172 ± 22b	42 ± 5b	24 ± 2c	84 ± 20b	98 ± 22b	26 ± 10a	20 ± 8a

TC=total cholesterol; GOT=glutamic oxaloacetic transaminase; GPT=gamma-glutamic pyruvic transaminase; HDL=high density lipoproteins; LDL=low density lipoproteins; TG=triglycerides

(1) Middle distance (1500 m), (2) Hammer throwing; (3) Means are not labeled by a common letter (a, b and c) and are significantly different between groups (P<0.05)

kinase (CK) can normally be observed during therapy. This is a worrying fact for athletes because, independently of statin therapy, they may have a high serum level of this enzyme after strenuous exercise, which can lead to muscle breakdown. Dehydration also occurs frequently in athletes, and can increase CK and induce rhabdomyolysis. This phenomenon has been frequently observed among athletes and is commonly associated with statin treatment. There are no clear studies that quantify the effect of statins during intense exercise. However, it is recommended to stop hypolipidemic therapy a week before endurance events (e.g. marathon), because dehydration in competitions increases the risk of rhabdomyolysis (Reamy, 2008).

When evaluating cardiovascular risk in an athlete, it is important to expect a better lipid profile compared to that of the baseline population and to take into account any supplements ingested to increase performance. Even though risks may arise, possible increases in serum lipids should be treated, while following the recommendations of statin therapy (Reamy, 2008).

A particular subject is that of women who practice high performance sport, as these female athletes often suffer from menstrual cycle disorders. Due to the small amount of calories ingested daily, in relation to energy expenditure, these women have a higher risk of developing eating disorders, osteoporosis and stress fractures. In studies comparing amenorrheic athletes to athletes with normal and regular menstrual cycles, it was found that those who had an abnormal menstrual cycle had higher TG and LDL levels. Unfortunately, there are no studies evaluating cardiovascular risk in this population (Reamy, 2008).

Conclusions

1. Former athletes gain weight and lose muscle mass especially because they do not adapt their diet to their new lifestyle.

2. Regular exercise does not provide protection against cardiovascular risk in high performance athletes. The sports in which obesity, metabolic syndrome and insulin resistance occur more frequently are American football, golf, baseball, boxing and sumo.

3. People with diabetes can achieve high levels of performance in sport. To compete without suffering severe changes in blood glucose concentrations, athletes must learn to coordinate carbohydrate intake and insulin administration.

4. A better glycemic control is achieved by reducing the pre-exercise insulin dose by 50-80% depending on the type, duration, intensity and familiarity of exercise.

5. The benefits of regular exercise in patients with diabetes are similar to those in people without this pathology (only when there is good glycemic control). The benefits of sports overcome potential problems caused by metabolic changes during exercise, as long as there is an adequate screening.

6. An intensive training program or participation in high-performance sport competitions may induce changes in the levels of serum laboratory parameters.

7. Sports activities induce a higher lipid profile compared to sedentary lifestyle.

8. Athletes who practice aerobics or short-distance running have higher HDLC levels. Swimmers, hammer throwers and wrestlers have lower triglycerides and total cholesterol levels.

9. It is recommended to stop hypolipidemic treatment a week before endurance events (e.g. marathon), because dehydration in competitions can increase the risk of rhabdomyolysis.

Conflicts of interest

Nothing to declare.

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