Physical exercise and metabolic syndrome

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ABSTRACT

Regular physical activity practice has been recommended for the prevention and rehabilitation of cardiovascular diseases and other chronic diseases by different health care associations worldwide, such as the American College of Sports Medicine, the Centers for Disease Control and Prevention, American Heart Association, National Institute of Health, the US Surgeon General, the Brazilian Society of Cardiology and many others. Epidemiologic studies have shown a direct relation between lack of physical activity and the presence of multiple risk factors such as those found in the metabolic syndrome. The regular practice of physical exercise has been show to have beneficial effects in the prevention and treatment of blood hypertension, insulin resistance, diabetes, dyslipidemia, and obesity. Physical training therefore should be encouraged for both healthy individuals and those with multiple risk factors if they are capable of participating in a physical fitness program. Just as clinical therapy helps to maintain the function of organs, physical activity promotes favorable physiological adaptations that result in an improved quality of life.

Key words: Metabolic syndrome. Physical activity. Exercise.

Physical inactivity and low physical conditioning level have been considered as risk factors for early mortality so important as the smoking, dyslipidemia and arterial hypertension[1]. Epidemiological studies have demonstrated direct relation between physical inactivity and the presence of cardiovascular risk factors such as arterial hypertension, insulin resistance, diabetes, dyslipidemia and obesity[2-5]. On the other hand, the regular practice of physical activity has been recommended for the prevention and treatment of cardiovascular disease, their risk factors and other chronic diseases[6-16].

The metabolic syndrome – also known as syndrome X, insulin resistance syndrome, deadly quartet or plurimetabolic syndrome – is characterized by the group of cardiovascular risk factors such as arterial hypertension, insulin resistance, hyperinsulinaemia, glucose intolerance/diabetes type II, central obesity and dyslipidemia (high LDL-cholesterol, high triglycerides and low HDL-cholesterol). Epidemiological and clinical studies have demonstrated that the regular practice of physical activity is important factor for prevention and treatment of this disease[2-5,11-16].

The objective of this reviewing is to demonstrate the role of the regular practice of physical activity in the prevention and treatment of the metabolic syndrome as well as to describe the amount and modality of exercise required for this purpose.

EXERCISE AND OBESITY

In the last decades, a rapid and increasing growth of obese people has been observed, what made the obesity a public health problem. This disease has been classified as a disorder primarily of high energetic ingestion. However, there are evidences suggesting that most cases of obesity are more related to the low energy expenditure than to the high food ingestion, where the physical inactivity of the modern life seems to be the highest etiological factor for the growth of this disease in industrialized societies[13].

Epidemiological and cohort studies have demonstrated strong association between obesity and physical inactivity[3-5]. Inverse association between physical activity, body mass index (BMI)*, hip-waist ratio (HWR)• and waist circumference has also been reported[2,3,5]. These studies demonstrate that the benefits of physical activity on obesity may be reached with low, moderate or high intensities, indicating that the maintenance of an active lifestyle, regardless what physical activity is performed, may avoid the development of this disease.

For the treatment of obesity, it is required that the energy expenditure be higher than the daily energy intake, what leads us to think that a simple reduction on the amount of food through alimentary diet is sufficient. However, it is not so simple and studies demonstrate that the change in the lifestyle through the increases on the amount of physical activity practiced and alimentary reeducation is the best treatment[16].

The energetic expenditure is composed of three main components: rest metabolic rate (RMR), thermic effect of physical activity and thermic effect of food (TEF). The RMR, which is the energetic cost to maintain systems functioning in rest, is the component of higher daily energetic expenditure (60 to 80% of the total). The obesity treatment only through dietary caloric restriction leads to a decrease on the RMR (through the decrease on the muscular mass) and on the TEF, what leads to a reduction or maintenance of weight reduction and to a tendency of returning to initial weight, despite the continuous caloric restriction, thus contributing to a long-lasting poor efficiency of this intervention[13]. However, the combination of caloric restriction and physical exercise helps to maintain RMR, improving the results of long-term weigh reduction programs. This occurs because physical exercise elevates RMR after its performance due to the increase on the substrate oxidation, catecholamine level and stimulation of protein synthesis[17,18]. This effect of the exercise on RMR may last from 3 hours until 3 days, depending on the type, intensity and duration of the exercise[19,20].

Other reason that encourages the inclusion of physical activities in weigh reduction programs is that the physical activity is the most variable effect of the daily energetic expenditure, where most people achieve generating metabolic rates 10 times higher during physical exercise with the participation of large muscular groups if compared to their values in rest such as fast walking, running and

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Received in 1/4/04. 2nd version received in 22/5/04. Approved in 25/5/04.

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* BMI – ratio between weight (kg) and the square height (m^2).

• HWR – ratio between circumferences (cm) of waist and hip.

swimming[13,20]. Athletes who train 3 to 4 hours a day may increase the energetic expenditure in almost 100%[20]. Under regular circumstances, the physical activity is responsible for 15 to 30% of the daily energetic expenditure (figure 1).

Activity	45 kg	68 kg	90 kg
Pedaling 10 km/h	160	240	312
Walking 3.2 km/h	160	240	312
Walking 4.8 km/h	210	320	416
Walking 7.2 km/h	295	440	572
Trotting 11 km/h	610	920	1,230
Running 16 km/h	850	1,280	1,660
Swimming	185	275	385

Figure 1 *– Approximate energetic expenditure per hour of a person (45, 68 and 90 kg) performing physical activity*

Although most studies have investigated the effect of the physical exercise on the weight reduction, the inclusion of the weight-resistance exercise (weightlifting) shows many advantages. The weight-resistance exercise is a powerful stimulus to increase mass, strength and muscular power also helping to preserve musculature, which trends to decrease due to diet, maximizing the reduction of the body fat[21-23]. Furthermore, its potential in improving strength and muscular resistance may be especially positive in daily tasks, furthering the adoption of a more active lifestyle in inactive obese individuals[16].

The traditional recommendation of at least 150 weekly minutes (30 minutes, 5 times a week) of physical activity from light to moderate intensities, which is primarily based on the effects of the physical activity on the cardiovascular disease and other chronic disease such as diabetes, demonstrates not being sufficient for weigh reduction programs. Thus, it has been recommended that exercise programs for obese individuals start with a minimum of 150 weekly minutes in moderate intensity progressively increasing up to 200 to 300 weekly minutes at the same intensity[16]. However, if for any reason the obese could not reach this target, he should be encouraged to perform at least the minimum recommendation of 150 weekly minutes, once with no weight reduction, there will be benefits to health[24-26].

EXERCISE AND INSULIN RESISTANCE

The association between physical inactivity and insulin resistance was suggested for the first time in 1945[27]. Since then, transversal and intervention studies have demonstrated direct relation between physical activity and insulin sensibility[2,5,28,29].

Transversal studies demonstrate lower levels of insulin and higher insulin sensibility in athletes, when compared to their inactive congeners[30-32]. Master athletes demonstrate being protected against glucose tolerance deterioration associated to aging[33,34]. However, short-duration physical activity is associated to low insulin sensibility and a few day of rest is associated to the increase on the insulin resistance[2,5,35].

It has been demonstrated that one single physical exercise session increases the glucose disposition by means of the insulin in normal subjects, in individuals with insulin resistance who are blood relatives of individuals with diabetes type 2, in obese individuals with insulin resistance as well as in individuals with diabetes type 2, and the chronic physical exercise improves the insulin sensibility in healthy individuals, non-obese, non-diabetic and in individuals with diabetes types 1 and 2[13,36-38].

Despite the clear benefit of the physical activity practice on the insulin sensibility, there are situations in which the acute exercise does not improve the insulin sensibility and it may even worsen it. The insulin sensibility is decreased after the marathon running[39], as well as after exhausting and eccentric exercise such as running up in a steep street[40], where a probable explanation for this fact is the increased and continuous utilization of fatty acids as muscular fuel. However, these are extreme conditions in which the exercise intensity is higher than the intensity that most individuals with metabolic syndrome can stand.

The effect of the physical exercise on the insulin sensibility has been demonstrated from 12 to 48 hours after the exercise session, however, it returns to pre-activity levels in 3 to 5 days after the last physical exercise session[13], what reinforces the necessity to practice physical exercises with frequency and regularity.

The fact that only one exercise session improves the insulin sensibility and that the effect provided by the training withdraws in a few days of inactivity arises the hypothesis that the physical exercise effect on the insulin sensibility is merely acute. However, it has been demonstrated in a study in which individuals with insulin resistance improved the insulin sensibility in 22% after the first exercise session and in 42% after 6 weeks of training[41], what demonstrates that the physical exercise presents both an acute effect and a chronic effect on the insulin sensibility.

Benefits of the physical exercise on the insulin sensibility are demonstrated both in the aerobic exercise and in weight-resistance exercise[41-45]. The mechanism through which these exercise modalities improve the insulin sensibility seems to be different[42], what suggests that the combination of both exercise modalities may be additive.

EXERCISE AND DIABETES TYPE 2

Epidemiological and intervention studies clearly demonstrate that the regular practice of physical exercises is effective for the prevention and control of diabetes type 2[14,46-49]. The regular practice of physical exercises have demonstrated to decrease the risk of developing diabetes type 2 both in men and women, regardless the family history, weight and other cardiovascular risk factors such as smoking and hypertension[46,47]. Intervention studies have demonstrated that changes in the lifestyle with the adoption of new alimentary habits and the regular practice of physical exercises decrease the incidence of diabetes type 2 in individuals with glucose intolerance[49,50], where the performance of at least four weekly hours of physical activity from moderate to intense intensity decreased 70% the incidence of diabetes type 2 on average, in relation to the inactive lifestyle after four years of follow-up[49].

The practice of physical activity has also been considered as an important tool in the treatment of individuals with diabetes type 2[51]. Physical exercise programs have demonstrated to be effective in the glycemic control of diabetic individuals, improving the insulin sensibility and the glucose tolerance and decreasing the blood glicemy of these individuals[14,48,52].

The performance of aerobic exercises have been generally recommended for individuals with diabetes type 2[48,50,52]. However, recent studies have demonstrated that the weight-resistance exercise is also beneficial in the glycemic control of individuals with diabetes type 2[12,53-55].

The weight-resistance exercise may be especially useful for aged diabetic individuals, once during aging, the muscular strength and mass decreases, undesirably affecting the energetic metabolism (figure 2). The increase on the muscular mass and strength through the practice of weight-resistance exercises may revert this situation, improving the glycemic control of these individuals[45]. Thus, decreases on the blood glucose levels, increases on the muscular glycogen supply, reduction on the systolic pressure and trunk fat have been demonstrated as well as increases on the muscular mass and daily physical activity levels of aged diabetic individuals from both gender after 16 weeks of weight-resistance exercises, what resulted in reduction on dedication up to 72%, while individuals who participated in the control group presented unchanged blood glicemy levels, systolic pressure, trunk fat and daily physical activity and decreased muscular glycogen supplies and 42% had increased medication[14].

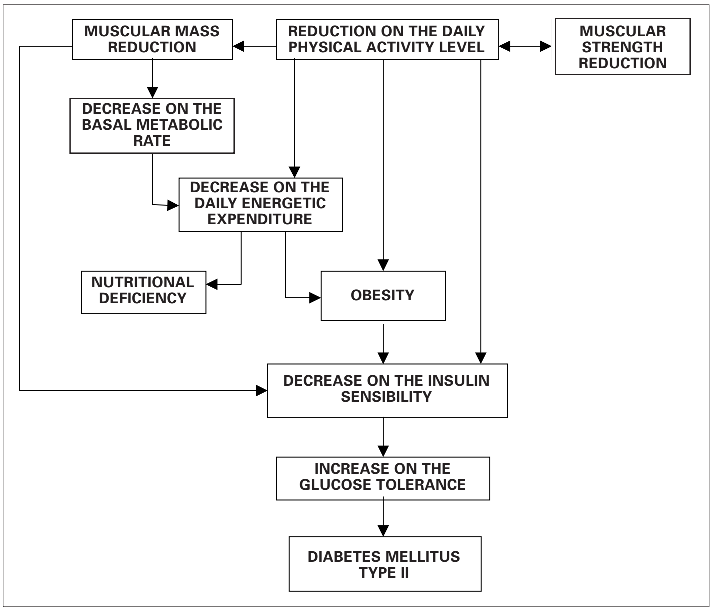

***Figure 2** – Effect of the strength and muscular mass reduction occurring with aging in several metabolic variables associated to metabolic syndrome. Adapted from Ciolac and Guimarães with the authors' consent[45].*

EXERCISE AND ARTERIAL HYPERTENSION

Epidemiological and clinical studies have demonstrated beneficial effects of the practice of physical exercises on the arterial pressure in individuals of all ages. High level of daily physical activity is associated to lower levels of arterial pressure in rest[56]. The regular practice of physical exercises have demonstrated to prevent blood pressure increases associated to age[57,58] even in individuals with increased risk to develop it[59]. Physical activity programs have demonstrated to decrease the systolic and diastolic blood pressure both in hypertensive and normotensive individuals[12,60,61].

These benefits of the physical activity on blood pressure make physical activity an important tool on prevention and treatment of the hypertension[12]. A meta-analysis of 54 controlled randomized longitudinal studies that investigated the effect of the aerobic physical activity on the blood pressure demonstrated that this exercise modality reduces 3,8 mmHg and 2,6 mmHg the systolic and diastolic pressures on average, respectively[12]. Reductions of only 2 mmHg on the diastolic pressure may reduce significantly the risk of diseases and deaths associated to hypertension[62], what demonstrates that the practice of aerobic exercise represents important benefit for health in hypertensive individuals.

It has been proposed that the effect of the aerobic exercise on the blood pressure is more due to the acute effect of the last exercise session than to the training cardiovascular adaptations[13]. In this context, the study performed by our research group demonstrated that hypertensive individuals presented reductions on the blood pressure clinical monitoring during 24 hours (MAPA 24 h) when performed shortly after the last exercise session, which were not observed when performed 72 hours after the last session[63].

Hypertensive individuals have been traditionally discouraged to perform weight-resistance exercises due to the fear that this exercise modality would cause a cerebrovascular or cardiac event. However, studies that investigated the effect of long periods of weight-resistance exercise training on the blood pressure in rest reported no harmful effects, suggesting that hypertensive individuals should not avoid its practice, once it provides relevant benefits to quality of life, especially for aged individuals[42,45].

EXERCISE AND DYSLIPIDEMIA

The effects of the physical activity on the lipids and lipoprotein profiles are well known. Individuals physically active present higher levels of HDL-cholesterol and lower levels of triglycerides, LDL and VDLL-cholesterol, if compared to inactive individuals[65].

Intervention studies demonstrate the unfavorable lipids and lipoprotein profiles improve with physical training[64]. These improvements are not dependent on gender, body weight and diet, however, there is a possibility of being dependent on the glucose tolerance degree[13,51,64,65]. The physical activity has demonstrated to be effective in decreasing the level of VLDL-cholesterol in individuals with diabetes type 2, however, except for a few, most studies have not demonstrated significant improve on levels of HDL and LDL-cholesterol in this population maybe due to the low intensity of the exercise employed[51].

Although studies on the effect of physical exercises on the lipids and lipoprotein profiles in individuals with metabolic syndrome are scarce, considering the evidences above and the fact that physical exercises increase the ability of the muscular tissue in spending fatty acids and the activity of the enzyme lipoprotein lipase in the muscle[66], it is likely that the physical exercise be effective in improving the lipid and lipoprotein profiles in individuals with metabolic syndrome.

PRESCRIPTION OF PHYSICAL EXERCISE

In the practice or prescription of physical training with the objective of obtaining some training physiological effect, either the improvement of the physical conditioning or the prevention and treatment of diseases, one should take into account four basic principles. The first is the overload principle that commends that in order to obtain physiological response with physical training, the physical exercise should be performed with an overload above the usual, which could be controlled with intensity, duration and exercise frequency. The second principle is the specificity principle, which is characterized by the fact that exercise specific modalities unchain specific adaptations that further specific physiological responses. The third principle is the individuality principle, where the biological individuality of each group should be respected in the prescription of some exercise program, once the same overload and exercise modality will cause responses of different magnitude in different individuals. The fourth and last principle is the reversibility principle, which is characterized by the fact that the physiological adaptations furthered by the physical exercise performance return to the pre-training original state, when the individual returns to the inactive lifestyle[20].

The performance of at least 30 minutes of physical activity (performed formally or in the spare time, continuously of concentrated in sessions of at least 10 minutes) of intensity at least moderate (level 12 in the Borg* scale – fig. 3) performed in most days of the

6.
7. Very easy
8.
9. Easy
10.
11. Relatively easy
12.
13. Slightly tiring
14.
15. Tiring
16.
17. Very tiring
18.
19. Exhaustive
20.

***Figure 3** – Borg scale of effort subjective perception*

* The Borg scale of effort subjective perception (fig. 3) is a useful tool for intensity monitoring in exercise programs, once it is associated with the response of the cardiac frequency, blood lactate, pulmonary ventilation and $\dot{V}O_{2max}$ to exercise.

week (preferably all), where a total expenditure of 700 to 1000 kcal (kilocalories) a week is achieved, has been proposed for the health maintenance and prevention of a large variety of chronic diseases[6-9].

However, in order for the benefits and health security of the regular practice of physical activity to be maximized, a prescription of exercises that takes into account the necessities, aims, initial capacities and family history is required[20,67,68]. Furthermore, for the treatment of some diseases such as obesity, this amount of exercises has demonstrated being not sufficient[16]. These factors lead us to believe that the individual with metabolic syndrome, since they present risk factor for cardiovascular diseases, will obtain higher benefits with the regular practice of physical exercise if it is individually planned, aimed at the improvement of his health state and taking into account his health state, risk factors and physical capacity as well as his history and aims.

The amount of researches on the effects of the weight-resistance training on metabolism is small if compared to researches involving aerobic exercises.

However, based on current reviewing studies[20,65,66] we propose that a physical activity program aimed at the prevention and treatment of the metabolic syndrome should include components that improve the cardiorespiratory conditioning, strength and muscular resistance.

The performance of these exercises are based on the following reasons:

– Both weight-resistance and aerobic exercises further substantial benefits related to health and physical conditioning (figure 4) including most risk factors of the metabolic syndrome[13,42].

Variable	Aerobic exercise	W. resistance exercise
Glucose metabolism		
Glucose tolerance	↓↓	↓↓
Insulin sensibility	↑↑	↑↑
Seric lipids		
HDL cholesterol	↑↔	↑↔
LDL cholesterol	↓↔	↓↔
Blood pressure in rest		
Systolic	↓↔	↔
Diastolic	↓↔	↓↔
Body composition		
% of fat	↓↓	↓
Body mass free of fat	↔	↑↑
Basal metabolism	↑	↑↑
Muscular strength	↔	↑↑↑
Aerobic capacity		
$\dot{V}O_{2max}$	↑↑↑	↑↔
Time of maximal or submaximal aerobic exercise	↑↑↑	↑↑

↑ = increase on values; ↓ = reduction on values; ↔ = unchanged values; ↑ or ↓ = small effect; ↑↑ or ↓↓ = intermediate effect; ↑↑↑ or ↓↓↓ = large effect; HDL cholesterol = high-density cholesterol; LDL cholesterol = low-density cholesterol.

***Figure 4** – Effect of the aerobic and weight-resistance exercise on variables that influence the metabolic syndrome and physical conditioning*

– The mechanisms through which weight-resistance and aerobic exercises affect some variables of the metabolic syndrome such as the insulin resistance, the glucose intolerance and obesity seem to be different[14,16,42] and the sum of the effects from both activities may occur.

– With aging, the strength and muscular mass, which are associated to a series of dysfunctions including metabolic dysfunctions are decreased (figure 3) and the performance of weight-resistance exercise may prevent or control this situation[42,45].

– The physical conditioning, which is defined as the ability of performing physical activity from moderate to intense levels with no excessive fatigue and the capacity to maintain this ability along life are important parts of good quality of life, and the performance of weight-resistance and aerobic exercises along with flexibility exercises has been exhaustedly recommended for the improvement and maintenance of the physical conditioning as well as for the prevention and rehabilitation of cardiovascular diseases in adults of all ages[6,42,68-71].

Although the minimal dose of exercise required to reach many of the health benefits is known, the optimum dose for prevention and treatment of most disorders is yet unknown.

With regard to aerobic exercises, it has been recommended to be performed from 3 to 6 times a week with intensity from 40 to 85% FCR* (40 to 85% of the $\dot{V}O_{2max}$, or 55 to 90% of the FCmax or level 12 to 16 in the Borg scale) and duration of 20 to 60 minutes[7,68]. Due to the fact that higher exercise intensities is associated to higher cardiovascular risk and orthopedic lesions and the lower adherence to physical exercise programs[68], it is recommended that programs aimed at inactive individuals with risk factor for cardiovascular diseases emphasize moderate intensity (50 to 70% of the FCR and levels 12 to 13 in the Borg scale) and long duration (30 to 60 minutes)[9,68].

The current recommendation for the practice of weight-resistance exercise is 1 series of 8 to 12 repetitions (10 to 15 for individuals above 50/60 years of age), intensity of 50 to 70% of the maximal load♦ (13 to 15 in the Borg scale) performed with 8 to 10 exercises working all large muscular groups 2 to 3 times a week[7,67,68]. However, this recommendation is only based on strength improvement and muscular resistance[72]. The performance of a higher number of series (2 to 3) will increase the energetic expenditure of the exercise session, increasing the activity benefit for individuals with metabolic syndrome.

Thus, we recommend that individuals with metabolic syndrome start with 1 series, progressively increasing up to 2 and 3 series after adaptation.

All aerobic and weight-resistance physical activity sessions should include warm-up and calm down with the use of flexibility exercises at the beginning and at the end of each session (figure 5).

Evaluation	To perform ergometric test before practice preferentially by the time the patient will perform the activity and making use of medication (in diabetic individuals, to evaluate the presence of peripheral artery disease, retinopathy, renal disease and autonomic neuropathy).
Prescription	To develop individualized exercise prescription for aerobic and weight-resistance exercise based on the physical evaluation in the objective of the program, in the patient and in the resources available. Aerobic exercise: frequency = 3-5 days a week; Intensity = start with 50% progressively increasing up to 70% of the $\dot{V}O_{2max}$ (50 to 70% of the FCR or 60 to 85% of the maximal cardiac frequency; Duration = 30 – 60 minutes; Modality = walking/running, cycle-ergometer or swimming. Weight-resistance exercise: Frequency = 2-3 days a week; Intensity = 8 to 12 RM (10 to 15 for individuals above 50/60 years of age) for each large muscular group; Duration = start with 1 series progressively increasing up to 2 and 3 series; Type = bodybuilding machines, free weights, elastic bands, body weight, etc. To include warm-up and relaxation exercises as well as flexibility exercises in all sessions.
Results	The physical exercise will help cardiovascular risk factors, improve functional capacity and welfare and increase participation in domestic and recreative activities.

***Figure 5** – Recommendations for physical activity*

* FCR – store cardiac frequency, which is calculated through the formula: FCR = (FCmax – FCrep) x I + FCrep, where: FCmax = maximal cardiac frequency; FCrep = rest cardiac frequency; and I = exercise intensity.

♦ Maximal load – the heaviest weight lifted one single time using good movement form and technique.

CARES FOR THE PRACTICE OF PHYSICAL ACTIVITY

Despite the beneficial effect of the physical activity on prevention and treatment of diseases, it is known that the risk related to a cardiovascular event or muscle-skeletal lesion during the practice of physical exercise is higher than in usual activities[68]. Thus, some cares must be taken in relation to the practice of physical activity by patients with metabolic syndrome.

Before entering a physical activity program, any individual must be evaluated with regard to recent clinical history. For individuals with metabolic syndrome, it is recommended the performance of ergometric test for the cardiovascular evaluation. In case the ergometric test presents no abnormalities, no other evaluation is required, except for individuals with diabetes type 2. However, if test presents some abnormality, the individual must perform other tests according to necessity and the exercise prescription will be according to exercise recommendations for individuals with cardiovascular disease[7].

Individuals with diabetes type 2, besides the cardiovascular evaluation, the evaluation of the presence of peripheral artery disease is recommended (signals and symptoms of intermittent claudication, decrease or absence of pulse, atrophy of subcutaneous tissue, etc.) retinopathy, renal disease and autonomic neuropathy[51]. It is important to emphasize that none of these disease hinders the patient's participation in physical activity programs; however, they influence the modality and intensity of the exercise to be prescribed.

It should be given special attention to the adequate clothing during the practice of physical activity. The use of light and comfortable clothes is recommended (T-shirts, trunks or tactel or cotton trousers). When walking or running is performed, the use of comfortable shoes with soft sole and good impact absorption is recommended[73]. The hydration control before the beginning and during the exercise session also deserves attention, especially in diabetic individuals[20,51].

For diabetic patients, special attention should be given to feet and glycemic control. The use of soft insoles as well as the use of cotton socks in order to keep feet dry is important to reduce injuries. The patients should be educated to verify constantly the appearance of blisters and any other type of injury, before and after each exercise session. In patients making use of insulin or other medication for blood glicemy control, one should pay attention to the medication timetable so that the patient does not perform exercises in hypoglycemic state.

All the authors declared there is not any potential conflict of interests regarding this article.

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