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Review

High Intensity Interval Training - As good as in Athletes as in subjects with Metabolic Syndrome?

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Abstract

HIIT training (high intensity interval training) is one of the most effective means of improving both cardio-respiratory and metabolic functions as well as physical performance of athletes. It includes a series of intensive physical exercises (e.g. running until reaching 90% of the maximum possible pulse), with intermittent rest periods. Active intervals can range between 45 and 240 seconds and alternate with easy exercise periods or even rest periods. This type of training is based on a different principle than regular exercises, where the effort is constantly dosed with an average intensity over a longer period of time. Initially, these exercised were used for practicing performance athletics, but they were also adopted by the fitness world for their efficacy in burning fat, which has been demonstrated in multiple studies. It has been observed that the attainment of the maximum cardiovascular performance and peripheral adaptation by athletes is determined by reaching 90% of the maximum aerobic capacity [VO2max]. Thus, new trends in sports medicine structure specific training protocols that allow 90% of VO2 max to be maintained for long periods of time. Moreover, there is evidence that HIIT influences cardiovascular response, anaerobic glycogenesis, blood glucose levels, neuromuscular yield, and musculoskeletal tension, parameters that can be improved not only in athletes but also in individuals with metabolic syndrome. The HIIT recommendation is made after considering a number of factors such as the intensity and duration of the exercise as well as the recovery period, the exercise mode, and the number of repetitions and series.

Keywords : HIIT, athletes, metabolic syndrome

Highlights

- ✓ The choice of HIIT, both for the training of athletes and for the improvement of cardiovascular and metabolic function, should be taken into account more frequently in the therapeutic management of patients with metabolic syndrome.
- ✓ There are insufficient data to establish the exact glycemic response determined by HIIT two hours after glucose loading. Most research shows glycemic control between 24 and 72 hours.

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Introduction

HIIT training (high intensity interval training) is one of the most effective means for improving both cardio-respiratory and metabolic functions as well as the physical performance of athletes. Training consists of a series of intensive physical exercises (e.g. running until reaching 90% of the maximum possible pulse), interleaved with rest periods. Exercises are performed by repeating short activities of 45 to 240 seconds, alternating with rest periods (1).

This type of training is based on a different principle than regular exercise, where the effort is constantly dosed with an average intensity over a longer period of time. HIIT training originated in the 1920s and has improved over time. It was initially applied to those practicing performance athletics, but it has also been adopted by the fitness world due to its efficacy in burning fat, demonstrated now through numerous studies (1).

The attainment of the maximum cardiovascular performance and peripheral adaptation by athletes is determined by reaching 90% of the maximum oxygen absorption or aerobic capacity [VO2max]. Thus, new trends in sports medicine structure specific training protocols that allow 90% of max to be maintained over long periods of time. Other variables that are influenced by this type of exercise are cardiovascular response, anaerobic glycogenesis, neuromuscular output, and musculoskeletal tension (1).

The HIIT recommendation is made after considering a number of factors such as the intensity and duration of the exercise and the recovery period, the exercise mode, and the number of repetitions and series. Any manipulation of these variables determines an acute response to HIIT (1, 2).

For those athletes who train several times a day or practice team sports using both the metabolic component and the neuromuscular component that determines the use of anaerobic energy, HIIT training is indicated to avoid overload and to adapt to effort (2). Several approaches to HIIT ultimately determine the metabolic response or neuromuscular adaptation. Therefore, the ability of the coach to understand the athlete's response to HIIT will influence the chosen program type (2).

The relationship between the exercise and the recovery period is very important in HIIT training. Current studies look for the optimal balance between exercise and relaxation to improve the performance and benefits of this exercise. A concrete example is the 1 to 1 ratio—3 minutes of intense exercise followed by 3 minutes of relaxation. The standard exercise period can vary by 3, 4, or 5 minutes and is followed by the same duration of relaxation. Another variant of HIIT is the sprint interval method. This consists of performing 30 seconds of extreme exercise until close to exhaustion, followed by 4-5 minutes of recovery. The exercise can be repeated 3 to 5 times per session (3).

Therefore, nine variables can be considered when prescribing HIIT sessions. The key factors are the intensity and duration of work and the recovery intervals. Also, the number of series performed or the number of recovery series between exercises influences the total work done. The type of the chosen training (running at the same level vs. ramp, cycling, canoeing, etc.) has not yet been extensively studied as a separate variable, but must be considered in the HIIT programming. In conclusion, the manipulation of each variable both in isolation and individually has an impact on metabolism or cardio-pulmonary and neuromuscular response (4).

Discussions

1. HIIT and the cardiovascular response

Cardiovascular adaptations to regular and constant physical exercise are currently well known. During exercise, cardiac performance depends on the heart rate, the stroke volume, and the myocardial contractile force. The physiopathological mechanism during physical exercise depends on changing these variables by increasing blood flow and the oxygen reserve to cope with the demand for muscle contraction during exercise. Also, the contraction of the skeletal muscles results in increased venous return to the heart (preload) with increased ventricular filling. These changes contribute to increased cardiac output during physical exercise, a major factor in the anaerobic activity of the heart (5).

Chronic changes in the myocardium for long-term sports activities consist in the thickening of the myocardium and left ventricular hypertrophy, adaptations that help improve the cardiac performance during exercise. Practicing resistance exercises such as running or cycling 3 to 7 times per week for 30 minutes will cause the following adaptive changes (6):

- Increased stroke volume
- Increased cardiac muscle mass
- Increased elimination of metabolic wastes
- Increased oxygen penetration into muscle
- Enhancement of oxidation enzymes and effectiveness
- Increased intra-chamber volume of the left ventricle and its consequent dilation
- Increased fat oxidation
- Increased fat consumption
- Increased cellular metabolism
- Increased mitochondrial energy
- Increased fatigue strength of contracted muscle fibers

The maximum oxygen consumption [VO2 max] is the body's ability to consume, distribute, and use oxygen in order to produce energy, and it is a good predictor of sports performance. Thus, the latest rehabilitation tendencies in patients with cardiovascular disease consist of the improvement of the cardiovascular function and the increase of VO2 max. By comparison, HIIT training is able to contribute a 15% increase in VO2 max, compared with only 9% for endurance exercises (7).

Adaptive changes in the cardiac structure in subjects with metabolic diseases consist in the reduction of the telediastolic volume (TDV) and left ventricular wall hypertrophy. HIIT workouts have been shown to cause a physiological hypertrophy of the myocardium with increased left ventricular wall thickness and telediastolic volume. Currently, data that accurately describe the type of cardiac changes in patients with metabolic diseases is lacking. What has been seen so far is an improvement in the HIIT telediastolic volume in patients with type-2 diabetes, a change that does not occur among those with non-alcoholic liver steatosis (7).

From the point of view of the evaluation of the systolic function in patients with metabolic diseases, the stroke volume and the ejection fraction are the two variables that are reduced. Moreover, in patients with heart failure, a global increase by 22% in cardiac contractility has also been observed. These changes were not noticed in patients who had a moderate exercise program (8).

During cardiac contraction, epicardial fibers dominate, in comparison with endocardial fibers, due to torsion forces. In patients with metabolic diseases, this force is increased, which causes the alteration of endocardial fibers. HIIT manages to reduce this force in patients with type-2 diabetes and non-alcoholic hepatic status, thus reducing endocardial destruction (9).

In patients with metabolic diseases, the main change during diastole is the decrease of ventricular filling. This causes the thickening and destruction of muscle fibers, with decreased compliance during relaxation. HIIT training for 12 weeks helps improve ventricular filling, as compared to medium intensity exercise for a comparable time. These changes were also observed one year after the exercise program, which shows that the intensity of training is a variable that determines the improvement of the diastolic function, an independent mortality predictor (10).

It is known that atherosclerosis may occur due to endothelial dysfunction associated with metabolic diseases. Endothelium is essential in maintaining vascular tone. It is involved in regulating blood flow in response to the perfusion requirements of tissues and organs. Thus, when the blood flow in a vessel increases, this causes vasodilation. This phenomenon is called flow-mediated dilation (FMD) and it is altered according to nitric oxide levels. HIIT has been shown to be superior to moderate physical exercise in FMD improvement due to increased shear stress during high intensity training, which results in increased nitric oxide release (10). Cardiovascular changes in HIIT are therefore similar or, in some cases, superior to those during classical exercise.

In performance athletes using large muscle groups during training, a temporal gap between the warm-up period and the beginning of the HIIT training is recommended in order to reach VO2 max as quickly as possible. The intensity of physical exercises during warm-up training should be less than 60% of VO2 max, with team or racquet sport type training. Regardless of the type chosen, athletes should reach VO2 max for 5 minutes [for team or racquet sports] or 10 minutes [for endurance sports] (10).

The importance of adaptive changes to high cardiac frequencies with respect to continuous ventricular filling compared to the repeated one has not yet been studied. Using 90-95% of VO2 max for more than 4 minutes will increase muscle fatigue by lowering the load, so HIIT exercises with time-adjusted intervals are preferable (10).

2. HIIT and the metabolic response

Since no fixed method has been established in the assessment of anaerobic metabolism in HIIT, the measurement of the accumulation of oxygen or lactate concentration is currently used. Thus, studies show that athletes who practice long-lasting physical exercises (e.g. those practicing athletics) have higher serum levels and will more likely require the additional use of anaerobic energy (11).

Increasing the duration of exercise without changing the rest period will clearly increase anaerobic metabolism. Studies show that in those who practice athletics, increasing the running time by 20 seconds, from 2 minutes and 10 seconds to 2 minutes and 30 seconds in order to reach 100% of the VO2 max will almost double the serum lactate compared to the initial value (12). Adding jumping after each sprint was also correlated with a slight increase in lactate, probably as a consequence of increased muscle activity. On the other hand, the increase from 1 to 6 minutes but with a decrease in intensity from 93% to 84% of VO2 max will maintain its serum level at a constant value. Thus, the manipulation of HIIT variables with short intervals can facilitate the change of the anaerobic energy level used. Generally, the longer the duration of intervals or increased intensity, the greater the increase in the level of accumulated lactate (11).

In patients with metabolic diseases, decreased mitochondrial function has been observed, contributing to insulin resistance. In adults with type-2 diabetes who underwent two weeks of HIIT-type training, there was an increase in mitochondrial activity, highlighted by the increase in citrate synthase activity and the electron transport chain; whereas after two weeks of gentle walking, only changes in the mRNA expression, not its function, were observed (9).

HIIT workouts have induced muscle changes by increasing skeletal muscle working capacity and decreasing fatigue. This is due to the increase from 50 to 60% in the retention of calcium in the sarcoplasmic reticulum during these exercises, compared to a normal exercise program (9).

3. HIIT and the neuromuscular response

Due to the differences between athletes and the type of training performed, the various forms of HIIT training can have different musculoskeletal and neuromuscular effects. For example, athletes practicing endurance sports will practice long HIIT sessions while athletes practicing team sports will choose short sessions.

Currently there are insufficient data to demonstrate the exact neuromuscular response to different forms of HIIT. A 2002 study submitted 14 handball players to 3 different forms of HIIT: initially, the athletes underwent two rapid HIIT series consisting of 12 springs of 5 seconds with relaxation of 25 seconds, another series of 10 seconds of effort with 20 seconds of relaxation, and another series of 30 seconds of effort with 30 seconds of relaxation. The height and strength of the jumping was substantially improved after the 10-second intense training with 20 seconds of relaxation, while after the other two types of HIIT performance, it was poor. During the first type of exercise, an increase in anaerobic energy was observed, provided that a high but not maximum running speed was achieved. This could potentially trigger the post-activation potential that led to improved jumping performance. Although during the other two types of exercise the maximum speed was reached and the anaerobic glycolytic energy was increased, the performance achieved was low. These findings show that intense exercise per se does not induce muscle fatigue and that muscle metabolic imbalance is sufficient to induce neural and muscle changes (11).

Thus, reaching more than 80-85% of VO2 max requires the activation of striated muscle fibers that initiates the post-activation potential and probably determines long-term adaptations that help resist fatigue during high intensity effort. On the other hand, the supramaximal effort with over 100% of VO2 max is associated with decreased muscle performance.

In addition to achieving performance, any accidents that may occur must be taken into account, as well as muscle pain and cramping. Because during these exercises, the majority of the forces that occur are located in the lower limbs and increase proportionally to the running speed, the prevention of complications in this type of exercise can be achieved by choosing lower intensity exercises performed on non-slippery and less harsh surfaces (for example on synthetic tracks or grass, rather than on asphalt). In conclusion, the pattern followed, the type of exercise [cycling, running], the type of surface where the activity is carried out [pavement, synthetic trail, sand, grass], and the land type [straight, slope or ramp] all have a direct impact on the risk factors and must be considered according to a risk/benefit analysis (11).

4. HIIT and the glycemic control

The desired acute phase response of the body after a HIIT workout is to lower blood glucose levels within normal limits in patients with decreased glucose tolerance. This effect appears to last up to 72 hours post-workout, shorter than in the case of regular moderate exercise sessions.

Increased blood glucose levels from the period of the exercise itself to the post-exercise period are closely related to muscle contraction. Thus, intense exercises determine the participation of larger muscle groups over moderate exercises, which explains the favorable response of the HIIT (13).

In terms of lowering pre-prandial blood glucose, some studies show that HIIT causes it to decrease, others show a response comparable to post moderate intensity exercise.

The pre-prandial glycaemia value is often a marker of hepatic insulin resistance. Thus, in patients with type-2 diabetes, after a week on a diet of only 600 kcal/day, the lipid content of the liver decreases by 30%, and insulin resistance improves and basal blood glucose decreases by 35%. These changes are similar to those occurring after HIIT or moderate intensity exercises and are related to the fact that physical exercises result in less energy shortage than that obtained with a change in the diet. For example, in order to get an energy burn after ingesting a 450 kcal cake, a 68-year old woman should run for about 40 minutes at a speed of 10 km/h (9).

Peripheral insulin sensitivity will improve after HIIT training in patients with metabolic syndrome, mediated through the effects of this exercise on metabolic changes: increased aerobic enzymes and mitochondrial biogenesis. Thus, when comparing HIIT and moderate exercise with regard to the benefit of insulin resistance, it seems that HIIT training is superior (9).

In adults with type-2 diabetes compared to a control group, a decrease in glycosylated hemoglobin was also observed. This effect is especially important given that a 1% increase in glycosylated hemoglobin will increase the risk of diabetes mellitus by 21% and the risk of myocardial infarction by 14% (14). There are insufficient data to establish the exact glycemic response determined by HIIT two hours after glucose loading. Most of the research shows glycemic control between 24 and 72 hours.

Conclusions

The choice of HIIT, both for the training of athletes and for the improvement of cardiovascular and metabolic functions, should be considered more often in the therapeutic management of patients with metabolic syndrome.

Conflict of interest disclosure

There are no known conflicts of interest in the publication of this article. The manuscript was read and approved by all authors.

Compliance with ethical standards

Any aspect of the work covered in this manuscript has been conducted with the ethical approval of all relevant bodies and that such approvals are acknowledged within the manuscript.

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