SUMMARY
Elite endurance athletes have long appreciated the role for HIT as part of a comprehensive training program. Recent evidence shows that — in young, healthy persons of average fitness — intense interval training is a science-efficient strategy to elicit maximal skeletal muscle adaptations comparable to those achieved by traditional endurance training. As little as six sessions of HIT over two weeks, or a total of ~15 min of total training time, can increase oxidative capacity in skeletal muscle and improve performance during tasks that rely mainly on aerobic energy metabolism. However, fundamental adaptations that can be elicited and maintained over the long term such as maximal aerobic capacity and the maximal capacity for oxygen and by altering substrate metabolism in working skeletal muscle can increase oxidative capacity in skeletal muscle and improve performance during tasks that rely mostly on aerobic energy metabolism.

INTRODUCTION
High-intensity interval training (HIT) — performed with “all out” efforts or at an intensity ≥ 90% of VO2peak — is generally thought to be an inadequate volume for at least several weeks — increases aerobic energy metabolism, improves performance, and induces metabolic adaptations in skeletal muscle (Kubekeli et al., 2005; Ross & Leveritt, 2001). HIT enhances the expression of metabolic proteins in human skeletal muscle after repeated sessions of relatively brief, intermittent exercise, such as sprint-type exercise training, which is generally thought to be an inadequate volume for at least several weeks — increases aerobic energy metabolism, improves performance, and induces metabolic adaptations in skeletal muscle (Kubekeli et al., 2005; Ross & Leveritt, 2001). HIT enhances the expression of metabolic proteins in human skeletal muscle after repeated sessions of relatively brief, intermittent exercise, such as sprint-type exercise training, which is generally thought to be an inadequate volume for at least several weeks — increases aerobic energy metabolism, improves performance, and induces metabolic adaptations in skeletal muscle (Kubekeli et al., 2005; Ross & Leveritt, 2001).

NEW INSIGHTS
While the underlying mechanisms are unclear, metabolic adaptations associated with traditional high-volume endurance training can be expected to differ from those observed with HIT. Recent evidence suggests that similar adaptations are associated with traditional high-volume endurance training and HIT, which are not induced by previously thought to be insufficient training volumes. Recent evidence suggests that similar adaptations are associated with traditional high-volume endurance training and HIT, which are not induced by previously thought to be insufficient training volumes.

KEY POINTS
• High-intensity interval training (HIT) is characterized by repeated sessions of relatively brief, intermittent exercise, often performed with “all out” effort or at an intensity close to that which elicits peak oxygen uptake (i.e., ≥ 90% of VO2peak).
• Although similarly associated with improved “sprint” type performance, studies have shown that HIT has a divergent response of skeletal muscle carbohydrate metabolism during exercise and signaling pathways normally associated with endurance training.
• As little as six sessions of HIT over two weeks, or a total of ~15 min of total training time, can increase oxidative capacity in skeletal muscle and improve performance during tasks that rely mostly on aerobic energy metabolism.
• While the underlying mechanisms are unclear, metabolic adaptations associated with HIT could be induced in part through signaling pathways normally associated with endurance training.

REFERENCES
Skeletal Muscle Adaptations to HIT

Similar to traditional endurance training on strength training, the intensity and duration of HIT depend on the precise nature of the training stimulus. However, unlike the former two types of exercise that primarily rely on either cardiovascular endurance or muscle endurance (strength), energy needs to fuel ATP production, the bioenergetic requirements of high-intensity exercise can often be adequately met through repeated short bursts of intense exercise separated by moments of recovery. To address these problems, we conducted a series of studies that measured skeletal muscle adaptations to prolonged periods of exercise, in terms of energy metabolism and exercise capacity after a given training session can be derived primarily from non-oxidative (glycolytic) systems (e.g., ATP-PC and glycogen) and a decreased ability to stimulate ATP production through oxidative metabolism. The reader is referred to a recent review for a comprehensive overview of skeletal muscle adaptations to a prolonged period of exercise (Juel et al., 2006). Our studies have consistently found an increased muscle oxidative capacity (assessed using the maximal activity of enzymes such as citrate synthase and cytochrome c oxidase) that is normally associated with increased endurance training, including an increased resting glycogen content and reduced rate of glycogen utilization during repeated sprint or running-effort work (Figure 2a) and in vivo conditions (Figure 1a) (Burgomaster et al., 2007; 2006). In fact, high-intensity exercise we found to be a stimulus for mitochondrial protein content and citric acid cycle enzymes (e.g., Complex I, II, and IV), as well as metabolic capacity (e.g., mitochondrial protein content and long-chain fatty acids (VCT) and (sCitrat) in FABP) (Burgomaster et al., 2007). Our findings are consistent with previous studies that were performed in vitro (e.g., 1995-45% of total) (Blomström et al., 2007). All studies were performed on healthy college-aged men and women who were habitually active but not engaged in any structured training programs.

In addition to an increased skeletal muscle oxidative capacity after two weeks of HIT, we have also observed changes in carbohydrate metabolism that are normally associated with traditional endurance training, including an increased resting glycogen content and reduced rate of glycogen utilization during repeated sprint or running-effort work (Figure 2a) and in vivo conditions (Figure 1a) (Burgomaster et al., 2007; 2006). Synergy of the latter study; however, each training session consisted of ten 30-second sprints at 90% of peak power output interspersed by 4 min of recovery — for a total of only 2-3 fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workload — from ~26 min to 51 min fixed submaximal workflow...
Short-term HIT Rapidly Improves Exercise Capacity From a practical perspective, one of the most striking findings from our short-term Wingate-based training intervention is the exercise performance defects that may arise with individuals who are not trained for anaerobic output (Burgomaster et al., 2005, 2006, 2007; Githa et al., 2006). Indeed, in one study we used the Wingate test to determine the doubled length of time that exercise could be maintained at ~90% of peak VO2 (pre-training VO2peak) — only after 2 HIT sessions (Figure 3). The validity of this finding was bolstered by the fact that a control group showed a change in performance that was not sustained with the same training intervention. Subsequent work confirmed the validity of two weeks of HIT improved performance during tasks that more closely resembled normal athletic competition, including ~30 min that combined cycling and running from ~2 km in 4 (Burgomaster et al., 2006, 2007; Githa et al., 2006).

Obviously, the factors responsible for training-induced improvements in exercise capacity are complex and are determined by numerous physiological (e.g., cardiovascular, muscular, metabolic, neural, regulatory) and psychological attributes (e.g., mood, motivation, perception of effort). We have found no meaningful change in VO2peak after two weeks of HIT training (Burgomaster et al., 2005). However, the trained individuals increased carbohydrate metabolism that are normally associated with increased mitochondrial mass and oxidative activities (see references in Gibala et al., 2006). Moreover, β-hydroxyacyl-CoA dehydrogenase (HAD) and the muscle synthase and cytochrome oxidase) ranging from ~15-35% of the control values that the mitochondrial activity is associated with increased glycogen storage (Table 1). This study is the first study to demonstrate that HIT is indeed a very 'time-saver' strategy to induce additional muscular adaptations (Burgomaster et al., 2006, 2007; Githa et al., 2006).}

Skeletal Muscle Adaptations in HIT Similar to traditional endurance training on strength training, the exercise stimulus in HIT is dependent on the precise nature of the training stimulus, including the type of exercise, the duration and volume of exercise, and the intensity of exercise (Parolin et al., 1999). However, unlike the two other types of exercise that primarily rely on either oxidative endurance or anaerobic (strength) energy, high-intensity exercise is an ATP-PO4-adenosine-requiring (adenosine triphosphate-phosphate) process mediated by the Krebs cycle and/or electron transport chain. However, if the exercise bout is repeated three times with intervals of ~1 h (Burgomaster et al., 2006; 2007; Gibala et al., 2006). Obviously, the factors responsible for training-induced improvements in exercise capacity are complex and are determined by numerous physiological (e.g., cardiovascular, muscular, metabolic, neural, regulatory) and psychological attributes (e.g., mood, motivation, perception of effort). We have found no meaningful change in VO2peak after two weeks of HIT training (Burgomaster et al., 2005). However, the trained individuals increased carbohydrate metabolism that are normally associated with increased mitochondrial mass and oxidative activities (see references in Gibala et al., 2006). Moreover, β-hydroxyacyl-CoA dehydrogenase (HAD) and the muscle synthase and cytochrome oxidase) ranging from ~15-35% of the control values that the mitochondrial activity is associated with increased glycogen storage (Table 1). This study is the first study to demonstrate that HIT is indeed a very 'time-saver' strategy to induce additional muscular adaptations (Burgomaster et al., 2006, 2007; Githa et al., 2006).}

Skeletal Muscle Adaptations in HIT Similar to traditional endurance training on strength training, the exercise stimulus in HIT is dependent on the precise nature of the training stimulus, including the type of exercise, the duration and volume of exercise, and the intensity of exercise (Parolin et al., 1999). However, unlike the two other types of exercise that primarily rely on either oxidative endurance or anaerobic (strength) energy, high-intensity exercise is an ATP-PO4-adenosine-requiring (adenosine triphosphate-phosphate) process mediated by the Krebs cycle and/or electron transport chain. However, if the exercise bout is repeated three times with intervals of ~1 h (Burgomaster et al., 2006; 2007; Gibala et al., 2006). Obviously, the factors responsible for training-induced improvements in exercise capacity are complex and are determined by numerous physiological (e.g., cardiovascular, muscular, metabolic, neural, regulatory) and psychological attributes (e.g., mood, motivation, perception of effort). We have found no meaningful change in VO2peak after two weeks of HIT training (Burgomaster et al., 2005). However, the trained individuals increased carbohydrate metabolism that are normally associated with increased mitochondrial mass and oxidative activities (see references in Gibala et al., 2006). Moreover, β-hydroxyacyl-CoA dehydrogenase (HAD) and the muscle synthase and cytochrome oxidase) ranging from ~15-35% of the control values that the mitochondrial activity is associated with increased glycogen storage (Table 1). This study is the first study to demonstrate that HIT is indeed a very 'time-saver' strategy to induce additional muscular adaptations (Burgomaster et al., 2006, 2007; Githa et al., 2006).
Skeletal Muscle Adaptations to HIT

Similar to traditional endurance training or strength training, the frequency, intensity and volume of work performed.

However, unlike the other two forms of exercise that primarily rely on aerobic endurance (metabolism of non-oxidative strength) energy to fuel ATP production, the bioenergetics of high-intensity exercise can alter immediately in a process called the depletion of glycogen and the diffusion and distribution of energy to stimulate ATP production (Ross & Leveritt, 2001).

Our studies have consistently found increased skeletal muscle oxidative capacity (assessed using the maximal activity or content of mitochondrial enzymes such as citrate synthase and cytochrome c oxidase (Figure 1). To our knowledge this was the first study to demonstrate that muscle mitochondrial function increased in response to HIT.

In an additional increased skeletal muscle oxidative capacity after two weeks of HIT, we also observed changes in carbohydrate metabolism that are normally associated with traditional endurance training, including an increased resting glycogen content and reduced rate of utilization during meal break exercise training (Figure 2). These changes are important because they lead to increases in fat oxidation and fat oxidation in response to HIT. For example, the sprint protocol was based on other studies from our laboratory (Burgomaster et al., 2005; 2006; 2007). Surprisingly, only a few studies have examined the effects of HIT on mitochondrial function in skeletal muscle. In contrast, in our most recent study, we measured increased muscle activity of cytochrome c oxidase in skeletal muscle after two weeks of HIT.

However, HIT is effective in the prevention of chronic diseases and premature mortality, including type 2 diabetes, hypertension, and obesity. HIT is probably the most popular form of exercise intervention. In the past two decades there has been a rapid increase in the use of HIT as a training protocol, particularly in the clinical population. It is now clear that HIT is a very effective form of exercise training, particularly for persons with various disease conditions (Rognmo et al., 2004; 2007; Ross & Leveritt, 2001).

This is doubtless related to its high level of muscle intensity and potential to stress type-II muscle fibers in particular (Gollnick & Hawley, 2007). In contrast, traditional endurance training may occur more slowly. For example, the duration of training programs needed to induce adaptations in a practical, time-efficient manner in humans has been shown to vary from 1 to 2 years (Gollnick & Hawley, 2007).

However, HIIT is not without its limitations. For example, the most popular form of HIT is the 20-40 second all-out work intervals performed each week for two weeks. The combination of training intensity and volume necessary to induce adaptations is relatively short (six sessions over two weeks), and it remains to be determined whether similar adaptations are seen in more chronic studies.

How Does HIT Stimulate Adaptations in Skeletal Muscle?

The skeletal muscle adaptations induced by HIT are complex and are likely mediated by multiple signaling pathways that play a role in promoting specific biological responses. For example, the primary signaling pathways that mediate skeletal muscle remodeling in response to HIT, which include the activation of specific transcription factors and the upregulation of specific gene expression.

For example, traditional endurance training may occur more slowly. For example, the combination of training intensity and volume necessary to induce adaptations is relatively short (six sessions over two weeks), and it remains to be determined whether similar adaptations are seen in more chronic studies. The combination of training intensity and volume necessary to induce adaptations is relatively short (six sessions over two weeks), and it remains to be determined whether similar adaptations are seen in more chronic studies. The combination of training intensity and volume necessary to induce adaptations is relatively short (six sessions over two weeks), and it remains to be determined whether similar adaptations are seen in more chronic studies.

In our recent studies we have consistently found increased mitochondrial activity and exercise capacity after two weeks of HIT, we also observed changes in key signaling pathways that play a role in promoting specific biological responses. For example, the primary signaling pathways that mediate skeletal muscle remodeling in response to HIT, which include the activation of specific transcription factors and the upregulation of specific gene expression.

In addition to increased skeletal muscle oxidative capacity after two weeks of HIT, we have also observed changes in key signaling pathways that play a role in promoting specific biological responses. For example, the primary signaling pathways that mediate skeletal muscle remodeling in response to HIT, which include the activation of specific transcription factors and the upregulation of specific gene expression.

For example, traditional endurance training may occur more slowly. For example, the combination of training intensity and volume necessary to induce adaptations is relatively short (six sessions over two weeks), and it remains to be determined whether similar adaptations are seen in more chronic studies.
REFERENCES
magnitudes of adaptations that can be elicited and maintained questions remain regarding the minimum volume of exercises to improve physiological well-being in various populations, the effectiveness of a given (two passing) center trainings, and the pros and cons of magnitudes of adaptations that can be elicited and maintained over the long runs.

SUMMARY
The Gatorade Sports Science Institute® was created to help athletes optimize their health and performance through research and education in hydration and exercise science.
For additional information: U.S.A. and Canada: 800.942.6687 (toll free) www.gSSI.org
The Gatorade Sports Science Institute® was created to help athletes optimize their health and performance through research and education in hydration and exercise science.
For additional information:

• High-intensity interval training (HIT) is characterized by repeated sessions of relatively brief, intense efforts. This type of training is especially advantageous for athletes participating in sports requiring short bursts of maximal effort such as sprinting, soccer, and cycling.
• HIT is associated with numerous health benefits, including improved aerobic and anaerobic performance, enhanced fat metabolism, and reduced body fat.
• HIT is also effective for improving bone density, muscle mass, and VO2 peak, which is a measure of maximum oxygen consumption during exercise.
• In addition to improved performance, HIT has been shown to improve metabolic markers such as insulin sensitivity and lipids.

INTRODUCTION

The magnitude of adaptations that can be elicited and maintained questions remain regarding the minimum volume of exercises to improve physiological well-being in various populations, the effectiveness of a given (two passing) center trainings, and the pros and cons of magnitudes of adaptations that can be elicited and maintained over the long runs.

REFERENCES

• Training for endurance and strength: lessons


What is HIT?

HIT is a type of training that involves repeated sessions of relatively brief, intense efforts against a heavy resistance or pace. These efforts are followed by a period of active recovery, which is typically much shorter than the time required for recovery from aerobic exercise. This allows athletes to maintain high performance levels for longer periods of time, increasing their overall endurance capacity.

How does HIT work?

HIT works by inducing a variety of physiological adaptations in the body. These adaptations include increased heart rate, stroke volume, and oxygen uptake, as well as improved muscle efficiency and oxidative capacity.

What are the beneﬁts of HIT?

HIT has been shown to improve a variety of performance and health outcomes, including:
- Increased aerobic capacity
- Improved anaerobic performance
- Enhanced fat metabolism
- Increased bone density
- Improved muscle mass
- Reduced body fat
- Increased VO2 peak
- Improved metabolic markers such as insulin sensitivity and lipids

How do I get started with HIT?

To get started with HIT, you should consult with a qualiﬁed health and ﬁtness professional to determine the appropriate training regimen for your individual needs. It is also important to warm up properly before starting any training regimen to avoid injury.

In conclusion, HIT is a powerful training method that can help athletes improve their performance and health outcomes. By incorporating HIT into your training program, you can achieve a variety of beneﬁts that will help you reach your full potential.

INTRODUCTION

HIT is a type of training that involves repeated sessions of relatively brief, intense efforts against a heavy resistance or pace. These efforts are followed by a period of active recovery, which is typically much shorter than the time required for recovery from aerobic exercise. This allows athletes to maintain high performance levels for longer periods of time, increasing their overall endurance capacity.

What is HIT?

HIT is a type of training that involves repeated sessions of relatively brief, intense efforts against a heavy resistance or pace. These efforts are followed by a period of active recovery, which is typically much shorter than the time required for recovery from aerobic exercise. This allows athletes to maintain high performance levels for longer periods of time, increasing their overall endurance capacity.

How does HIT work?

HIT works by inducing a variety of physiological adaptations in the body. These adaptations include increased heart rate, stroke volume, and oxygen uptake, as well as improved muscle efficiency and oxidative capacity.

What are the benefits of HIT?

HIT has been shown to improve a variety of performance and health outcomes, including:
- Increased aerobic capacity
- Improved anaerobic performance
- Enhanced fat metabolism
- Increased bone density
- Improved muscle mass
- Reduced body fat
- Increased VO2 peak
- Improved metabolic markers such as insulin sensitivity and lipids

How do I get started with HIT?

To get started with HIT, you should consult with a qualified health and fitness professional to determine the appropriate training regimen for your individual needs. It is also important to warm up properly before starting any training regimen to avoid injury.

In conclusion, HIT is a powerful training method that can help athletes improve their performance and health outcomes. By incorporating HIT into your training program, you can achieve a variety of benefits that will help you reach your full potential.

INTRODUCTION

HIT is a type of training that involves repeated sessions of relatively brief, intense efforts against a heavy resistance or pace. These efforts are followed by a period of active recovery, which is typically much shorter than the time required for recovery from aerobic exercise. This allows athletes to maintain high performance levels for longer periods of time, increasing their overall endurance capacity.

What is HIT?

HIT is a type of training that involves repeated sessions of relatively brief, intense efforts against a heavy resistance or pace. These efforts are followed by a period of active recovery, which is typically much shorter than the time required for recovery from aerobic exercise. This allows athletes to maintain high performance levels for longer periods of time, increasing their overall endurance capacity.

How does HIT work?

HIT works by inducing a variety of physiological adaptations in the body. These adaptations include increased heart rate, stroke volume, and oxygen uptake, as well as improved muscle efficiency and oxidative capacity.

What are the benefits of HIT?

HIT has been shown to improve a variety of performance and health outcomes, including:
- Increased aerobic capacity
- Improved anaerobic performance
- Enhanced fat metabolism
- Increased bone density
- Improved muscle mass
- Reduced body fat
- Increased VO2 peak
- Improved metabolic markers such as insulin sensitivity and lipids

How do I get started with HIT?

To get started with HIT, you should consult with a qualified health and fitness professional to determine the appropriate training regimen for your individual needs. It is also important to warm up properly before starting any training regimen to avoid injury.

In conclusion, HIT is a powerful training method that can help athletes improve their performance and health outcomes. By incorporating HIT into your training program, you can achieve a variety of benefits that will help you reach your full potential.
SUMMARY
Elite endurance athletes have long appreciated the role of HIT as part of a comprehensive training program. Recent evidence shows that — in young healthy persons of average fitness — intense interval exercise is a time-efficient strategy to induce rapid metabolic adaptations that resemble changes usually associated with traditional endurance training.

Nicholas J. Gibala, PhD
Department of Kinesiology
McMaster University
Hamilton, Ontario
Canada

High-Intensity Interval Training: New Insights

INTRODUCTION
Regular endurance training improves performance during tasks that rely mainly on aerobic energy metabolism, such as maximal aerobic capacity and the maximal performance, many studies have shown that HIT for several cells signaling.

Although usually associated with improved "sprint"-type performance, metabolic adaptations associated with activities such as cycling or running and does not induce marked

While the underlying mechanisms are unclear, metabolic adaptations to HIT could be mediated in part through signaling pathways normally associated with endurance training.

The Gatorade Sports Science Institute® was created to help athletes optimize their health and performance through research and education in hydration and nutrition science.

For additional information: U.S.
and Canada: www.gatorade.com
International: www.gatoradesportsscience.com

© 2007 Gatorade Sports Science Institute

This article may be reproduced for non-commercial, educational purposes only.
WHAT CAN HIGH-INTENSITY INTERVAL TRAINING DO FOR YOU?

Martin J. Gibala, PhD
Department of Kinesiology
McMaster University
Hamilton, Ontario
Canada

Craig Ballantyne, CSCS, MSc
CB Athletic Consulting, Inc.
Toronto, Ontario
Canada

INTERVAL TRAINING generally refers to repeated sessions of relatively brief, intermittent exercise, in which short intervals of intense exercise are separated by longer periods of recovery. Depending on the level of exertion, a single effort may last from a few seconds to several minutes, with exercise intervals separated by up to a few minutes of rest or low-intensity exercise.

High-intensity interval training is often dismissed as being only for elite athletes. However, the basic concept of alternating high-intensity and low-intensity periods of exercise can be applied to almost any level of initial fitness. In addition, interval training is often based on subjective effort and does not necessitate working out at a specific heart rate or running speed. So while intervals may mean all-out running sprints for people with high levels of fitness, intervals can mean a brisk walk for others.

Benefits

- High-intensity intervals are a potent training stimulus. Even though the volume of exercise is quite small, a few brief sessions of intervals can cause adaptations similar to those associated with more prolonged periods of continuous moderate-intensity exercise.

- You only need to do intervals every other day, so you have more days off. This is great news for people who are pressed for time.

- Time flies. Not only will you be able to reduce your training time, but also the actual exercise component will zip by because of the alternating periods of intensity.

Limitations

- Discomfort. Intervals are very strenuous, and your legs will feel like jelly at the end of the workout. While you don’t have to exercise at 100% intensity to see results, you will have to leave your “workout comfort zone” if you want to achieve the benefits of high-intensity training.

- You will need to do an extended warm-up session if you plan on running sprints for your interval training sessions. Explosive running may increase your risk of injury compared to less weight-bearing activities such as cycling or swimming. If you run your intervals, try doing them up a hill.

- Be sure to dramatically reduce exercise intensity during the recovery periods between intervals. Most people do interval training incorrectly and do not permit themselves sufficient recovery. If you don’t recover adequately, you are not going to be able to work as hard during the exercise intervals.

- Before returning to strenuous training or competition after injuries, consult with an athletic trainer, personal trainer, sports medicine physician, or knowledgeable coach to make certain you have adequate strength in the previously injured limb(s).
The science behind interval training also helps to bury myths such as the “fat burning zone” and “it takes 30 minutes of exercise before your body begins to burn fat.” Skeptics often dismiss the fat loss potential of high-intensity exercise because the intervals are relatively short. But energy expenditure remains high during the recovery periods between exercise intervals, even though exercise intensity is dramatically reduced. To demonstrate this point, a recent study showed that only seven sessions of high-intensity interval training over two weeks increased fat burning during exercise by more than 30%.

As with any type of unaccustomed exercise, you should consult with your physician before beginning interval training. But high-intensity exercise in not “a heart attack waiting to happen.” Indeed, recent studies have applied high-intensity interval training strategies to patients with heart disease and reported greater improvement in health and fitness compared to traditional endurance training.

Sample Workouts

**Here’s a sample program for an absolute beginner (someone who can walk for 30 min at 3.5 mph):**

- Warm up: Five minutes of walking at 3.5 mph.
- Speed up and walk at 4.0 mph for 60 seconds.
- Slow down and stroll at 3.0 mph for 75 seconds.
- Repeat steps 2 and 3 five more times.
- Finish with 5 minutes of walking at a comfortable pace to cool down.

**Here’s an example of a more advanced workout for a person who is used to relatively vigorous exercise:**

- Warm up: Five minutes of easy jogging or light cycling.
- Run or cycle for 60 seconds at about 80-90% of your all-out effort. (Assume 100% equals the speed you would run to save your life, or cycle with as high a cadence as possible at the highest possible workload setting).
- Slow down to 30% of your all-out effort for 75 seconds. (Make sure to reduce intensity to a slow pace.)
- Repeat steps 2 and 3 five more times.
- Finish with 5 minutes at 30% of your all-out effort to cool down.

As you become more experienced, you can increase the intensity of the exercise intervals. You can also use different modes of exercise to do intervals. If you like to train outdoors, you can perform hill sprints or run in waist-deep water. If you are resigned to training at a commercial gym, you can choose between the treadmill, cross-trainer, stationary bike, and even the rowing machine. It all comes down to having the ability to increase the workload for a short amount of time and then being able to back off.

**COMMENT**

It is unlikely that high-intensity interval training produces all of the benefits normally associated with traditional endurance training. The best approach to fitness is a varied strategy that incorporates strength, endurance and speed sessions as well as flexibility exercises and proper nutrition. But for people who are pressed for time, high-intensity intervals are an extremely efficient way to train. Even if you have the time, adding an interval session to your current program will likely provide new and different adaptations. The bottom line is that — provided you are able and willing (physically and mentally) to put up with the discomfort of high-intensity interval training — you can likely get away with a lower training volume and less total exercise time.

**SUGGESTED ADDITIONAL RESOURCES**


