HIIT vs. Continuous Endurance Training

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HIIT vs. Continuous Endurance Training: Battle of the Aerobic Titans

by Micah Zuhl, MS, Len Kravitz, PhD

A Look at the Science of High-Intensity Interval Training.

The fitness industry is seeing a surge of interest in high-intensity interval training (HIIT), a burst-and-recover cycle that can offer a viable alternative to continuous aerobic exercise.

HIIT, which pairs quick bouts of high-energy exercise with low-effort rest intervals, is not exactly a new idea. As early as 1912, the Finnish Olympic long-distance runner Hannes Kolehmainen was using interval training in his workouts (Billat 2001). As our knowledge of HIIT has increased, exercise scientists have demonstrated that HIIT can

- boost the performance of competitive athletes;
- improve the health of recreational exercisers; and
- provide the benefits of continuous-endurance training with fewer workouts.

The standard way to improve cardiovascular fitness is to increase the volume of exercise—for example, with longer runs or bike rides, or more time on an aerobic machine. HIIT is intriguing because, according to current research, it can yield a broad range of physiological gains, often in less time than high-volume continuous exercise (Daussin et al. 2008).

With that in mind, this article will discuss the body's cardiovascular, skeletal-muscle and metabolic adaptations to HIIT and compare them with the body's responses to continuous endurance exercise. (Continuous aerobic training is defined as exercising—running, cycling, swimming, etc.—for more than 20 minutes at a steady intensity.) Also included here are research-based examples of HIIT and continuous endurance training.

Cardiovascular Physiology 101:

Basic Reponses and Adaptations of Aerobic Training

Before we can compare HIIT and continuous endurance training, it's important to review how the body's cardiovascular system adapts to an aerobic workout. During aerobic exercise, heart performance is based on heart rate, **stroke volume** (the amount of blood pumped per beat) and **heart contractility** (the forcefulness of each heart contraction). These variables increase blood flow and oxygen supply to meet the demands of exercising muscles.

The contraction of the skeletal muscle also boosts the flow of venous blood returning to the heart, which increases ventricle blood filling (called the **preload**). This elevated preload contributes to the heart's enhanced stroke volume during exercise, and this in turn is a major determinant of aerobic performance (Joyner & Coyle 2008).

Progressive increases in endurance training trigger adaptations in the heart muscle structure: heart muscle thickens, and the left ventricle expands, improving heart function during exercise. Consistent endurance exercise—such as 30–60 minutes of continuous running or cycling 3–7 days a week—causes a long list of cardiovascular adaptations and responses (see Figure 1).

HIIT vs. Continuous Endurance Exercise: Cardiovascular Adaptations

Recent research shows that the cardiovascular adaptations that occur with HIIT are similar, and in some cases superior, to those that occur with continuous endurance training (Helgerud et al. 2007; Wisløff, Ellingsen & Kemi 2009). Helgerud et al. showed that 4 repetitions of 4-minute runs at 90%–95% of heart rate maximum (HRmax) followed by 3 minutes of active recovery at 70% HRmax performed 3 days per week for 8 weeks resulted in a 10% greater improvement in stroke volume than did long, slow distance training 3 days per week for 8 weeks (total oxygen consumption was similar in both protocols).
Another study (Slørdahl et al. 2004) demonstrated that high-intensity aerobic training at 90%–95% of maximal oxygen consumption (VO2max) increased left-ventricle heart mass by 12% and cardiac contractility by 13%—improvements comparable to those observed with continuous aerobic exercise. VO2max is considered the body's upper limit for consuming, distributing and using oxygen for energy production. Commonly called maximal aerobic capacity, VO2max is a good predictor of exercise performance. Improving cardiovascular function increases the body's VO2max. Some research suggests that HIIT is better than endurance training for improving VO2max.

Daussin et al. (2008) measured VO2max responses among men and women who participated in an 8-week HIIT program and a continuous cardiovascular training program. VO2max increases were higher in the HIIT program (15%) than they were in the continuous training program (9%).

Improving cardiovascular function and increasing VO2max are major goals of patients with cardiovascular disease, which is why some cardiac rehabilitation centers are beginning to include interval training for heart disease patients (Bartels, Bourne & Dwyer 2010). Although traditional low-intensity exercise produces similar gains, improvements from interval training happen in a shorter time, with fewer sessions.

HIIT vs. Continuous Endurance Exercise: Skeletal-Muscle Adaptations

An increase in the size and number of **mitochondria** (the "energy factory" of a cell) is becoming a hallmark adaptation with HIIT (Gibala 2009). The increase in mitochondria density, as scientists call it, has been thought for many years to occur only from chronic endurance training.

During aerobic exercise, mitochondria use oxygen to manufacture high levels of **ATP** (adenosine triphosphate, the energy molecule of the cell) through the breakdown of carbohydrates and fat. As mitochondrial density increases, more energy becomes available to working muscles, producing greater force for a longer duration (allowing an athlete to run longer at a higher intensity, for example).
In a 6-week training study, Burgomaster et al. (2008) showed similar increases in levels of **oxidative enzymes** (proteins in mitochondria that accelerate biological reactions to liberate ATP) among subjects who performed a HIIT program consisting of four to six 30-second maximal cycling sprints (followed by 4.5-minute recovery bouts) 3 days per week and subjects who completed 40–60 minutes of steady cycling at 65% VO2max 5 days per week. An increase in mitochondrial oxidative enzymes leads to more effective fat and carbohydrate breakdown for fuel.

Related work by MacDougall et al. (1998) demonstrated higher levels of the oxidative enzymes citrate synthase (36%), malate dehydrogenase (29%) and succinate dehydrogenase (65%) in the skeletal muscle of healthy male undergraduate students engaging in 7 weeks of HIIT cycling sprints. Three days per week, subjects performed four to ten 30-second maximal cycling sprints followed by 4-minute recovery intervals. The higher levels of mitochondrial enzymes seen among the subjects led to improved skeletal-muscle metabolic function.

There has been a spike of current research explaining the complex molecular pathways that lead to increased mitochondrial density. HIIT can cause physiological changes that mirror the results of traditional endurance training, but the HIIT changes are accomplished through different message-signaling pathways (see Figure 2).

In this model, calcium–calmodulin kinase (CaMK) and adenosine monophosphate kinase (AMPK) are signaling pathways that activate peroxisome proliferator-activated receptor-g coactivator-1α (PGC-1α). PGC-1α is like a "master switch" that is believed to be involved in promoting the development of the skeletal-muscle functions shown in the figure. High-volume training appears more likely to operate through the CaMK pathway, whereas high intensity appears more likely to signal via the AMPK pathway.

HIIT vs. Continuous Endurance Exercise: Metabolic Adaptations

Increasing mitochondrial density can be considered a skeletal-muscle and metabolic adaptation. One focal point of interest for metabolic adaptations is the metabolism of fat for fuel during exercise. Because of the nature of high-intensity exercise, its effectiveness for burning fat has been closely examined. Perry et al. (2008) showed that fat oxidation, or fat burning, was significantly higher and carbohydrate oxidation (burning) significantly lower after 6 weeks of interval training.

Similarly, but in as little as 2 weeks, Talanian et al. (2007) showed a significant shift in fatty acid oxidation with HIIT. Horowitz and Klein (2000) reported that an increase in fatty acid oxidation was a noteworthy adaptation observed with continuous endurance exercise.

Another metabolic benefit of HIIT is excess postexercise oxygen consumption (EPOC). After an exercise session, oxygen consumption (and thus caloric expenditure) remains elevated as the working muscle cells restore physiological and metabolic factors in the cell to pre-exercise levels. This translates into higher and longer calorie burning after exercise has stopped.

In their review article, LaForgia, Withers and Gore (2006) noted that exercise-intensity studies indicate higher EPOC values with HIIT training than with continuous aerobic training.

Final Verdict: And the Winner of the Battle of the Aerobic Titans is . .

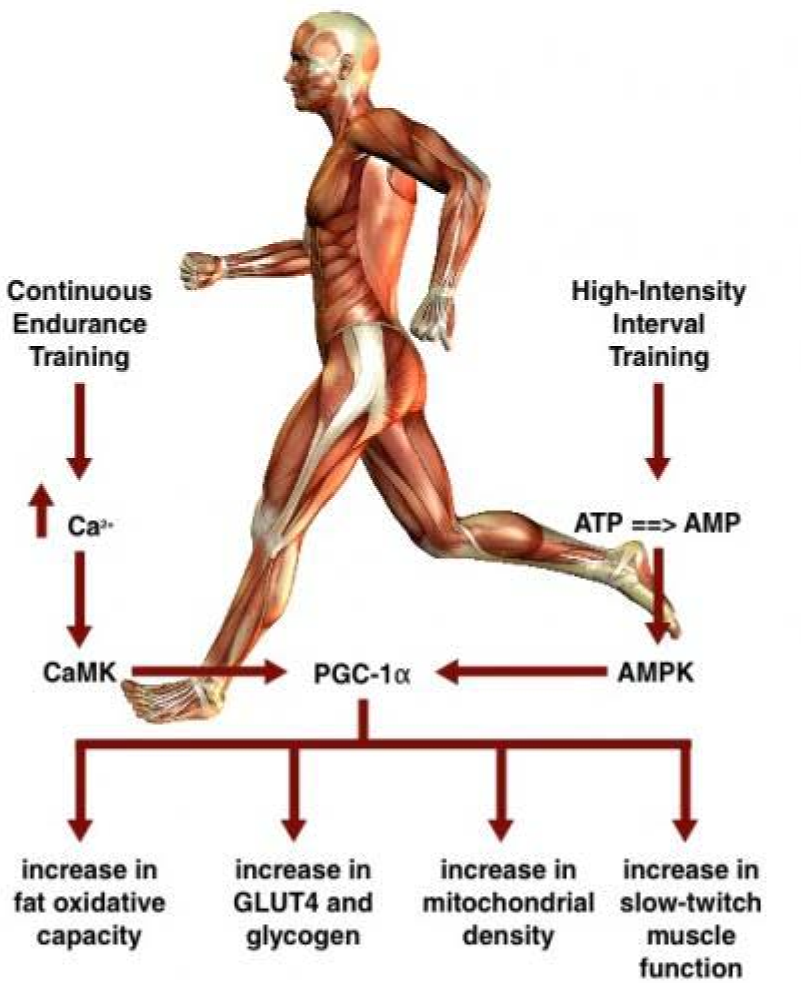
The major goals of most endurance exercise programs are to improve cardiovascular, metabolic and skeletal-muscle function in the body. For years, continuous aerobic exercise has been the chosen method for achieving these goals. However, research shows that HIIT leads to similar and, in some cases, better improvements in less time for some physiological markers. Incorporating HIIT (with appropriate intensity and frequency) into your clients' cardiovascular training gives them a time-efficient way to reach their goals.

And since both HIIT and continuous aerobic exercise programs improve all of these meaningful physiological and metabolic functions of the human body, incorporating a balance of both programs in clients' training is clearly the "win-win" approach for successful cardiovascular exercise improvement and performance. Go HIIT and go endurance!

Figure 1. Cardiovascular Responses and Adaptations to Endurance Training

Source: Joyner and Coyle 2008; Pavlik et al. 2010.

Figure 2. Signaling Pathways of Continuous Endurance Training and HIIT



Source: Laursen 2010.

4 Great Endurance Programs

The following endurance exercise programs are adapted from research investigations reviewed by LaForgia, Withers & Gore (2006). Perform an adequate warm-up (~10 minutes of light exercise) and cool-down (~5–10 minutes of low-intensity exercise) for each program. All of the workouts below can be performed on any aerobic mode.

1. Maximal-Lactate Steady-State Exercise

The maximal-lactate steady-state (MLSS) workout is the highest workload an exerciser can maintain over a specified time period. MLSS exercise work bouts can last 20–50 minutes. The client works at a maximal steady state of exercise for the desired time (20–50 minutes).

2. Alternating-Aerobic-Modes Endurance Exercise

The client alternates aerobic modes (treadmill and elliptical trainer, for example) every 20–40 minutes of aerobic exercise, keeping the exercise intensity at ≥70% HRmax. Time spent on each mode is the same. The number of alternating modes depends on the client's fitness level.

3. Stepwise Endurance Exercise

The client progresses from 10 minutes at ≥50% HRmax to 10 minutes at ≥60% HRmax to 10 minutes at ≥70% heart rate max on any aerobic mode. For a slight modification, the intensity might increase stepwise and then decrease stepwise as well. Thus, after completing the 10 minutes at ≥70% HRmax, the client would switch to 10 minutes at 60% HRmax and then 10 minutes at 50% HRmax.

4. Mixed-Paced Endurance Exercise

Using the selected mode of exercise, the program randomly varies endurance duration (e.g., 5-, 10- or 15-minute blocks) and exercise intensity. A 45-minute endurance treadmill workout could begin with 10 minutes at 50% HRmax, then sequence into 5 minutes at 70% HRmax, then 15 minutes at 60% HRmax, then 10 minutes at 75% HRmax, and finish with 5 minutes at 50% HRmax.

HIIT Program Development

Developing a HIIT program involves two prime considerations: the duration, intensity and frequency of the high-effort (or "work") interval; and the length of the recovery (or "rest") interval. The work interval can last from 5 seconds to 8 minutes. Power athletes tend to perform shorter work intervals (5–30 seconds), while endurance athletes will have longer work intervals (30 seconds to 8 minutes) (Kubukeli, Noakes & Dennis 2002). Intensity of the work interval should range from 80% to more than 100% of maximal oxygen consumption (VO2max), HRmax or maximal power output.

The intensity of the rest interval can range from passive recovery (very little movement) to the more common active recovery of about 50%–70% of the intensity measures described above.
The relationship of work and rest intervals is also a consideration. Many studies use a ratio of exercise to recovery. For example, a 1:1 ratio could be 30 seconds of work followed by 30 seconds of rest. A 1:2 ratio would be a 30-second work interval followed by a 1-minute rest. Typically, the ratio is designed to challenge a specific energy system of the body.

These workouts have been used in studies to induce cardiovascular and skeletal muscle changes. Each component of a training session is included.

PROGRAM 1:

Track Workout

Warm-up: Light 10-minute run around track.

Work interval: 800-meter run at approximately 90% of maximal heart rate (based on estimated HRmax: 220 − age). Each 800-meter interval should be timed.

Rest interval: Light jog or walk for the same time it took to run 800 meters.

Work-to-rest ratio: 1:1.

Frequency: 4 repetitions of this sequence, if possible.

Cool-down: 10 minutes of easy jogging.

Comments: The interval distance can be adjusted from 200 to 1,000 meters. Also, the length of the rest interval can be adjusted.

Source: Adapted from Musa et al. 2009.

PROGRAM 2:

Sprint Training Workout

Warm-up: 10 minutes of light running.

Work interval: 20-second sprint at maximum running speed.

Rest interval: 10 seconds of light jogging or walking after each sprint.

Work-to-rest ratio: 2:1.

Frequency: 3 groups or sets of 10–15 intervals. 4-minute rest between sets.

Cool-down: 10 minutes of easy jogging.

Comments: This is a sprint workout. The first few intervals should be slower, letting muscles adapt to the workout. It is important to avoid muscle damage during maximal sprinting. The warm-up session is very important.

Source: Adapted from Tabata et al. 1996.

PROGRAM 3:

Treadmill Workout

Warm-up: 10 minutes of light jogging.

Work interval: With treadmill incline at 5% grade and speed at 3 miles per hour (mph), switch to high-intensity interval—increasing speed to 5–6.5 mph—without changing grade. Each interval should be 1 minute.

Rest interval: Two minutes of walking at 3 mph. Do not adjust incline.

Work-to-rest ratio: 1:2.

Frequency: 6–8 repetitions of this sequence.

Cool-down: 5–10 minutes of easy jogging.

Comments: This is a hill-running interval session. Incline, running speed, interval length and rest interval can be adjusted.

Source: Adapted from Seiler & Hetleilid 2005.

4 Important Questions and Answers About HIIT

Q1. How many times per week can HIIT be completed?

A: Research says three times per week may produce the best results while limiting injury (Daussin et al. 2008; Helgerud et al. 2007; Musa et al. 2009; Perry et al. 2008). Interval training pushes the body hard, so it is important to be fully recovered between sessions.

Q2: Barefoot running has grown in popularity in the past several years. Is it safe to do HIIT barefoot?

A: It is important to progress slowly into barefoot running regardless of intensity (Pauls & Kravitz 2010). The best method may be to perform other daily living activities such as walking, cleaning or gardening before beginning to run. Once a client is consistently running barefoot, there should be another progression with HIIT. Best recommendation: Begin with one or two barefoot intervals and increase to three or four over several weeks.

Q3: If a client has been inactive for several months, is it safe to start an exercise program with HIIT?

A: Restarting any exercise program requires a careful progression of activity level. Beginning with HIIT may increase the chance for injury and muscle soreness. A better approach is to start with continuous, low-intensity aerobic exercise. A client who can run for 30 consecutive minutes at a moderate intensity can progress slowly into interval training.

Q4: Is it okay to eat before a HIIT session?

A: The stomach empties its contents more slowly when exercise intensity exceeds 80% VO2max (de Oliveira & Burini 2009), thanks to changes in blood flow and hormonal and neurotransmitter activations. Eating foods that are low in fiber, lactose and nutritive sweeteners several hours before training, and being sure to drink plenty of fluids, will reduce the chance of gut problems during exercise (de Oliveira & Burini 2009).

Reference:

Zuhl, M. & Kravitz, L. (2012). *HIIT vs. Continuous Endurance Training: Battle of the Aerobic Titans.* IDEA Health & Fitness Association. Retrieved from: http://www.ideafit.com/fitness-library/hiit-vs-continuous-endurance-training-battle-of-the-aerobic-titans

HIIT vs. Continuous Endurance Training
Home Study Exam

1. HIIT involves cycles of high intensity training followed by intervals of low-effort rest.
   A. True
   B. False

2. A benefit of HIIT compared to continuous endurance exercise is:
   A. A decrease in VO2 max
   B. Aerobic capacity improvements occur at a faster rate
   C. Stroke volume decreases
   D. The increased time exercising allows your body to burn off more stress

3. Which Improved cardiovascular function and adaptations are found in both HIIT and continuous endurance training:
   A. Increased fat oxidation, cardiac muscle mass and stroke volume
   B. Decreased fat oxidation, increased cardiac muscle mass and stroke volume
   C. Decreased cardiac muscle mass, increased fat oxidation and stroke volume
   D. Increased fat oxidation and cardiac muscle mass, and decreased stroke volume

4. Cardiovascular improvements with HIIT have been found to be equal to if not greater than continuous aerobic exercise.
   A. True
   B. False

5. The excess post-exercise oxygen consumption from HIIT also causes:
   A. Stress to the heart during recovery
   B. The lungs to accelerate your rate of breathing
   C. Fat storage in cells to increase
   D. An increase of calories burned following exercise

6. According to this article, improving cardiovascular endurance is best done by:
   A. Training only with HIIT
   B. Incorporating HIIT and continuous aerobic training together
   C. Weight training with compound sets
   D. Training only with continuous aerobic exercise

7. Continuous endurance training should be avoided by individuals with cardiac disease.
   A. True
   B. False

8. Designing a HIIT program includes:
   A. Considering the intensity and the duration of the work period
   B. Considering the intensity of the rest period
   C. Deciding the ratio of exercise and rest periods
   D. All of the above

9. HIIT should be performed at least 5 times a week to be effective.
    A. True
    B. False

10. Continuous endurance exercise is “the” superior method to utilize fat for energy.
    A. True
    B. False

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