SPORTSCIENCE sportsci.org

Perspectives: Endurance Training

# Effects of High-Intensity Intermittent Training on Maximum Oxygen Uptake and Endurance Performance

**Christian Finn**

Learn Fitness, Middlesex HA3 7EQ, United Kingdom.
Email: christian@thefactsaboutfitness.com

Sportscience 5(1), sportsci.org/jour/0101/cf.html, 2001 (1715 words)
Reviewed by John A Hawley, RMIT University, Melbourne, Australia

High-intensity intermittent training is a form of interval training consisting of short bouts of all-out activity separated by rest periods of between 20 s and 5 min. It is a low-volume strategy for producing gains in aerobic power and endurance normally associated with longer training bouts. Endurance athletes should gradually phase in bouts of high-intensity intermittent training in the build-up to competitions.

KEYWORDS: aerobic, anaerobic, athlete, fatigue, periodization

For an athlete to compete successfully in an endurance event, a maximum oxygen uptake ($VO_2$max) of at least 70 ml.kg$^{-1}$.min$^{-1}$ is a minimum requirement (Hawley et al., 1997). While athletes employ a variety of training strategies to increase $VO_2$max, recent research suggests that a form of interval training known as high-intensity intermittent training leads to rapid improvements in $VO_2$max and endurance performance.

Researchers from Canada's McMaster University recently investigated the effects of interval exercise on $VO_2$max (MacDougall et al., 1998). Training was performed on a stationary cycle ergometer for three days each week. The program began with four intervals lasting 30 s, separated by a 4-min rest period. By Week 7 the number of intervals had increased to 10, while the rest intervals were gradually reduced to 2.5 min. $VO_2$max increased by 9%, demonstrating that significant gains in $VO_2$max could be achieved from exercise of a relatively short duration. In the first week of the program, each training session lasted 14 min. By Week 7, the length of each training session had increased to 30 min.

A team from Japan's National Institute of Fitness and Sport found that a high-intensity intermittent training program achieved bigger gains in $VO_2$max than a program of steady cycling (Tabata et al., 1997). Active male subjects were assigned to one of two groups, each training 5 days per week for 6 weeks. One group followed a training program involving 60 min of moderate intensity exercise (70% $VO_2$max), for a total of 5 hours per week. The $VO_2$max in this group improved by an average of 9%. Training sessions of the other group consisted of eight all-out work bouts, each lasting 20 s, with 10 s of rest. This group cycled for a total of only 20 min per week, yet their $VO_2$max improved by 15%,

In addition to its effect on $VO_2$max, high-intensity intermittent training can improve athletic performance. Lindsay et al. (1996) reported that 4 weeks of interval training can improve 40-km time trial performance of competitive cyclists. The cyclists replaced approximately 15% of moderate intensity endurance training with high-intensity intermittent training, completing six interval sessions during the course of the study. Each interval session consisted of six to eight 5-min work bouts at 80% of peak power, separated by 60 s of recovery. The authors found significant improvements in 40-km time trial performance (54.4 ± 3.2 vs 56.4 ± 3.6 min) and time to fatigue at 150% of peak power (72.5 ± 7.6 vs 60.5 ± 9.3 s).

In a similar study, Stepto et al. (1999) examined the effect of five different types of interval training on performance of a 40-km time trial. The cyclists were assigned to one of five groups. Each group followed a different program, as shown in Table 1.

Table 1. Interval training programs of competitive cyclists in the study of Stepto et al. (1999)

| Group | No. of intervals | Work duration (min) | Rest duration (min) |
|---|---|---|---|
| 1 | 12 | 0.5 | 4.5 |
| 2 | 12 | 1 | 4 |
| 3 | 12 | 2 | 3 |
| 4 | 8 | 4 | 1.5 |
| 5 | 4 | 8 | 1 |

The cyclists replaced approximately 15% of their normal training with one of the interval exercise programs, completing six interval sessions over three weeks. Although the authors hypothesized that longer intervals would promote the greatest improvement in performance, the two programs providing the greatest gains in time trial speed were those with work bouts lasting 30 s and 4 min. The principle of specificity dictates that the body will adapt to the demands imposed upon it. The 4-min intervals were carried out at a pace similar to that of the time trial, and were expected to improve performance. A 40-km time trial depends almost entirely on energy provided by the aerobic system. Work bouts lasting 30 s depend primarily on anaerobic energy, and were not expected to enhance performance.

This paradox may be resolved by the findings of Rodas et al. (2000), who reported that a high-intensity intermittent training program increases oxidative enzyme activity in muscle. Rodas et al. evaluated changes in aerobic and anaerobic metabolism in active males following a short training program. Subjects performed two weeks of daily high-intensity intermittent training consisting of two 15-s all-out bouts separated by 45 s of rest, followed by two bouts of 30 s all-out sprints separated by 12 min of rest. Every two training sessions, an extra work bout was added. The last 3 sessions consisted of seven bouts of 15 s and seven bouts of 30 s. Maximum oxygen consumption increased from 57 ± 3 to 64 ± 3 $ml.min^{-1}.kg^{-1}$, and there were substantial increases in activity of citrate synthase (38%) and 3-hydroxyacyl-CoA dehydrogenase (60%). These changes in oxidative enzyme activity may increase the rate of fat oxidation and reduce carbohydrate oxidation. The subsequent reduction in the accumulation of hydrogen ions could improve endurance performance (Hawley et al., 1997).

It’s also interesting to note that an increase in training intensity can improve endurance performance without a change in $VO_2max$. Acevedo and Goldfarb (1989) tracked a group of trained male distance runners who increased their training intensity to 90-95% maximum heart rate for 8 weeks. There was an average 63 s reduction in 10-km race time and a significant decrease in plasma lactate at 85 and 90% of $VO_2max$, but no substantial change in $VO_2max$ (65.3 ± 2.3 vs 65.8 ± 2.4 $ml.kg^{-1}.min^{-1}$).

Although these studies provide evidence that high-intensity intermittent exercise can increase $VO_2max$ and improve endurance performance, the different work and rest ratios make it difficult for an athlete or coach to design an effective training routine. Furthermore, a periodized training schedule is likely to be more effective than a continuous program of high-intensity intermittent exercise. Hawley et al. (1997) suggested that a year-round training program should consist of three main phases. Phase one is performed during an athlete's non-competitive period, and consists of several months of moderate intensity, long duration exercise (60 min or more per session). The athlete then enters Phase two, involving two interval sessions per week. These interval sessions can replace two of the moderate intensity workouts. The work bouts during these interval workouts should consist of an intensity corresponding to race pace. For example, Stepto et al. (1999) used a total of eight work bouts (all carried out at race pace) each lasting 4 min with rest intervals of 90 s. Phase three, which begins approximately 21 days prior to the race, involves high-intensity intermittent training at maximum effort. This type of training is performed up to three times per week, and can consist of up to 12 work bouts lasting 30 s, with rest intervals of 4-5 min (Stepto et al., 1999). Gaskill et al. (1999) have presented evidence of the effectiveness of this kind of periodized program. In their study, cross-country skiers who had shown little improvement in competitive performance after a year of high-volume low-intensity training made substantial gains in the following year, when high-intensity intervals were phased in and the volume of low-intensity training was reduced.

The studies discussed in this article have used high-intensity intermittent exercise as a training intervention. However, the protocols varied widely. Some work intervals last between 15 and 30 s, while rest periods span 10 s to 4.5 min. More research is needed to establish the most effective form of interval training required to improve endurance performance.

## References

Acevedo EO, Goldfarb AH (1989). Increased training intensity effects on plasma lactate, ventilatory threshold, and endurance. Medicine and Science in Sports and Exercise, 21, 563-568

Gaskill SE, Serfass RC, Bacharach DW, Kelly JM (1999). Responses to training in cross-country skiers. Medicine and Science in Sports and Exercise, 31, 1211-1217

Hawley JA, Myburgh KH, Noakes TD, Dennis, SC (1997). Training techniques to improve fatigue resistance and enhance endurance performance. Journal of Sports Sciences, 15, 325-333

Lindsay FH, Hawley JA, Myburgh KH, Schomer HH, Noakes TD, Dennis SC (1996). Improved athletic performance in highly trained cyclists after interval training. Medicine and Science in Sports and Exercise, 28, 1427-1434

MacDougall JD, Hicks AL, MacDonald JR, McKelvie RS, Green HJ, Smith KM (1998). Muscle performance and enzymatic adaptations to sprint interval training. Journal of Applied Physiology, 84, 2138-2142

Rodas G, Ventura JL, Cadefau JA, Cusso R, Parra, J (2000). A short training programme for the rapid improvement of both aerobic and anaerobic metabolism. European Journal of Applied Physiology, 82, 480-486

Stepto NK, Hawley JA, Dennis SC, Hopkins WG (1999). Effects of different interval-training programs on cycling time-trial performance. Medicine and Science in Sports and Exercise, 31, 735-741

Tabata I, Nishimura K, Kouzaki M, Hirai Y, Ogita F, Miyachi M, Yamamoto K (1997). Effects of moderate-intensity endurance and high-intensity intermittent training on anaerobic capacity and $VO_2$max. Medicine and Science in Sports and Exercise, 28, 1327-1330

---

Edited and webmastered by Will Hopkins.
Published April 2001.