ANAEROBIC INTERVAL TRAINING IS NOT THAT WELL UNDERSTOOD OR DEFINED

Billat, L. V. (2001). Interval training for performance: A scientific and empirical practice. Special recommendations for middle- and long-distance running. Part II: Anaerobic interval training. Sports Medicine, 31, 75-90.

Anaerobic interval training is probably best described as "repeated maximal sprint training" or "supramaximal sprint training." It takes various forms and has vastly different training effects depending upon the intensity and duration of the work and the duration of the rest period. Consequently, there is little consensus in the literature with many studies varying too many factors, which obscure the actual mechanisms being used. Much of this form of training aims to improve anaerobic function, particularly glycogenolysis, but aerobic contributions and adaptations are also involved.

Fixed Work-rate Intervals

With short bouts (10-30 seconds) of intense exercise (150+% of vVO2max), it is the duration of the rest period that determines the energy systems employed. When very short rests (1:1 work:rest 10-15 seconds) are used, the adaptation is primarily aerobic. When rest periods exceed 30 seconds, the length of time it takes to allow the phosphagen pool to be resynthesized after very short maximum sprint efforts, work is primarily but not exclusively anaerobic. Athletes can perform many repetitions without increasing lactate above 2.5 mmol/kg. Thus, explosive intense effort interval training will elicit different metabolic characteristics depending upon the length of the rest interval employed.

Using short-short (ultra-short) interval work (10-15 seconds), the contribution of glycogenolysis to the total energy demand is considerably less than if work of a similar intensity was performed continuously (30-60 seconds). Supramaximal fixed work-rate interval training is most likely to tax both anaerobic and aerobic energy systems close to their maximum capacities.

Fixed Intensity Intervals

Typically, in this form of training the level of performance declines in the latter stages of the interval set. Most researchers have used longer work intervals (>30 seconds) and work:rest ratios of 1-4 or greater. With each successive repetition, the role of aerobic energy increases, particularly if CP has not fully resynthesized. In this form of interval training, CP is depleted extensively and takes longer to fully "recharge."

If coaches believe that longer duration sprints (>30 seconds), at or near maximum velocity, train the anaerobic pathways they are mistaken. With each successive trial, the role of aerobic metabolism increases, in concert with a decline in performance quality. One could assert that in repeated maximal sprint work, that if performance declines the contribution of anaerobic energy is relatively low and the aerobic energy contribution is quite high. In maximal sprint training, the rest periods have to be long enough to allow CP to be fully replenished so anaerobic energy sources will be maximally available for each repetition.

"To increase the glycolysis pathways, which account for 40 to 50% of the energy necessary to cover 100m, the intermittent training consists of a series of 100, 120, and 150m runs at 88 to 90% of the best performance with a passive rest of 5 to 6 minutes between each bout. However, in this protocol, it has been demonstrated that during passive rest almost all the CP was resynthesized after 4 minutes (from 19.8 to 36.9 mmol/kg dry muscle, instead of 39 ± 3.2 mmol/kg). The half time of CP resynthesis is 170 seconds." (p. 78)

To improve performance in competitions that last one minute (e.g., 1 km in track cycling, 100 m in swimming, 400 m in running), events that are normally performed at >150% VO2max, it is important to practice aerobic interval training, since the aerobic metabolism contribution is quite substantial.

"It is well know that both anaerobic pathways -- lactic (glycolysis) and alactic (CP degradation) -- are activated instantaneously at the onset of maximal activity. However, the ability to repeat maximal sprints depends on the duration of recovery, which does not have the same effect on the two anaerobic pathways. The resynthesis of CP depends on the endurance level of the participant" (p. 78). Glycogenolysis is largely elicited in supramaximal sprints, the work intensity being well above that which allows energy to be derived from lipids.

There is a relationship between the length of the supramaximal work bout and rest. The work:rest ratios increase as the duration of work increases. For example, in the sport of swimming, 10 seconds of work can be very easily balanced by rest periods of 10-20 seconds. However, one minute of appropriate work (i.e., near race-pace for the distance covered), would require more than five minutes of rest if a reasonable approximation of the first performance is to be repeated. Not only does the rest interval change with duration of supramaximal work, but also the number of repetitions is inversely proportional to the duration of work. To derive the most appropriate training stimulation, a coach has to determine these factors along with each individual's receptivity to this form of training. [The tendency seems to be to attempt to do too many repetitions, the latter experiences being largely detrimental to the training objectives and the individual's welfare.]

Long-term Physiological Effects

Many studies considering the long-term physiological effects of supramaximal sprint training have demonstrated an improvement in VO2max. However, there is a gender-specific response to achieve that state. Changes in aerobic power and submaximal heart rate for females are independent of repetition frequency, distance, and intensity. For men, it has been shown that training intensity, rather than frequency or distance, is the most important factor for improving VO2max.

One should not conclude that supramaximal sprint training is inefficient for improving anaerobic capacity. It has to be performed at a level of power output that greatly exceeds that associated with VO2max. Many studies have not worked subjects hard enough to stimulate the full recruitment of anaerobic energy or type II muscle fibers. If an athlete does not work with sufficient intensity to place the work well above the VO2max level, it is likely that training will be mainly aerobic in its effects. The most useful practical index of achieving significant anaerobic stimulation in a training bout is the demonstration of high lactate levels.

There is an important relationship between type I (aerobic) and type II (anaerobic) muscle fibers. Type I fibers are more involved in the removal of accumulated lactate than are type II fibers. To increase alactic anaerobic metabolism, supramaximal sprint training acts: (a) by increasing the ability to decrease CP as rapidly as possible if rest intervals are of sufficient length to allow the restoration of the CP reserve (avoiding the involvement of anaerobic glycolysis); and (b) by increasing the ability to replenish the CP reserve as quickly as possible. To accomplish the second effect, it is necessary to have muscle fibers with a high oxidative capacity, that is a trained aerobic base. However, when rest intervals are insufficient, anaerobic lactic metabolism (glycolysis) is increasingly involved. The resulting acidosis could impair CP production (via mitochondrial creatine kinase) during recovery (p. 80).

One valuable contribution of aerobic training to sprinting is the development of the capacity to replenish, most probably in an accelerated manner, CP reserves.

The amount of supramaximal sprint training required to produce desirable physiological changes is not great [in running]. Three to four repetitions of five minutes of effective high intensity interval training per week (~20 minutes) can result in an increase in both glycolytic and oxidative muscle enzyme activity, maximum short-term power output, and VO2max. The challenge for coaches is to NOT OVERDO this form of training. It is particularly debilitating when experienced in excessive amounts.

For events that are dominantly aerobic, but where an increased anaerobic contribution is required, such as when running the last lap of a 10K race in 52 seconds, interval training using short all-out bouts of exercise that elicit the glycolytic pathway should be used. Normally, supramaximal training of longer duration, such as one minute at ~130% of vVO2max with rests of five minutes is appropriate. Reports have suggested this training three times a week for eight weeks can produce pronounced changes.

This type of training does appear to be enhanced when diet is supplemented with creatine. Benefit is derived from a higher availability of phosphate or produced by an increased rate of CP resynthesis during recovery periods.

When training is designed to induce both anaerobic and aerobic energy supply, presumably because that is the "mix" of energy in competitions, it might be necessary to perform sets of intervals of different duration and rest periods. The short-task short-rest work will stimulate aerobic adaptation, whereas long work and extra long recovery will stimulate a greater amount of anaerobic adaptation along with the ever-present aerobic adaptation. If the tasks are performed at the same maximal velocity/intensity, neuromuscular patterning will be "conditioned" as well.

Implications for Training

Throughout the remainder of the paper, the author suggests various considerations for training. They are interpreted below and are tempered by this reviewer's own knowledge of these matters.

1. Generally, it is best to train at specific performance intensities/pace by modifying/adapting work and rest periods to produce the greatest volume of specific work. This will be an individual decision and should not be considered for groups of athletes.

2. Interval training is more acceptable by athletes than long periods of continuous training.

3. After extended periods of continuous training, performances no longer improve. The only avenue for improvement is to employ interval training where higher work quality can be experienced in significant amounts. For events where aerobic function dominates, improvement is produced by increasing both VO2max and the velocity at VO2max (vVO2max -- movement economy). Time spent at VO2max is much higher in interval work, especially in "short-short" (ultra-short) training.

4. When performing intervals, particularly short-short work, active recovery might be preferable to passive recovery. In some sports this is easy (e.g., rowing -- alternating fast and slow work), but in others difficult (e.g., swimming -- where distances and organization are important).

5. The response to interval training is gender specific. Thus, programming variables need to be considered differently when training males and/or females.

6. Young children usually tolerate shorter rest periods than adults.

7. The contribution of aerobic energy to work is higher in children than in adults.

8. Children have the same time limit at vVO2max as adults. Improvement in vVO2max is not accompanied by an improvement in the time limit at vVO2max.

9. Changes in aerobic and anaerobic functions in children are independent of physiological maturity.

10. When formulating any recipe for training, the paramount consideration should be for the individual. Interval training programs developed for groups are largely inappropriate for the majority of participants.

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