STUDIES

A graphical model for interval training

By Guy Thibault

ABSTRACT

The author proposes a model of the dynamic link between the components of an interval training session. It has several practical applications on a pedagogical level and for planning sessions and developing training programmes in aerobic sports, including cross country, middle and long distance running, in which maximal aerobic power, aerobic endurance and anaerobic capacity are key performance factors.

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Introduction

It has often been demonstrated that greater improvements in key performance factors (anaerobic capacity, maximal aerobic power [MAP] and aerobic endurance[1]) in most of the so called 'aerobic' sports such as cross country, middle and long distance running can be achieved through training programmes that include intermittent sessions. In fact, as shown in Table 1, when doing continuous exercise, one cannot sustain intensity in the optimal development zone of these key performance factors for very long. It is exactly because it enables an athlete to perform a greater amount of work at a given elevated relative intensity that interval training is frequently preferred to continuous training.

The following six elements are generally specified when an interval training session is designed:

◆ number of repetitions
◆ number of sets
◆ duration or distance of work intervals
◆ intensity of work intervals
◆ duration or distance of recovery periods between more intense work intervals and between sets
◆ intensity of recovery periods

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1 Not to be confused with VO_2 max or maximal aerobic power; aerobic endurance means the ability to maintain a given relative power output for a long period of time or to maintain, for a given length of time, an elevated relative power output.

Training Intensity (% MAP)	Potential Effect on:			Maximal time it can be sustained (h:min:s)		For an elite veteran runner with a HRmax of 180 and a VO$_2$max of approximately 70 mL O$_2$/kg/min	
	Anaerobic Capacity	Maximal Aerobic Power (MAP)	Aerobic Endurance	... for a LOW aerobic endurance runner	... for a HIGH aerobic endurance runner	Approximate running velocity (km/h)	Approximate corresponding heart rate (bpm)
110%MAP	+++++	++		3:00	3:00	22	Irrelevant
105%MAP	++++	+++		4:00	4:00	21	Irrelevant
100%MAP	+++	+++++	+	7:00	7:00	20	180
95%MAP	++	++++	++	11:00	15:13	19	174
90%MAP	+	+++	+++	17:00	32:54	18	168
85%MAP		++	++++	26:00	1:10:55	17	161
80%MAP		+	+++++	40:00	2:33:00	16	155
75%MAP			++++	1:02:00	5:30:00	15	149
70%MAP			+++	2:27:00	Very long	14	143
65%MAP			++	3:47:00	Very long	13	136
60%MAP			+	Very long	Very long	12	130
55%MAP				Very long	Very long	11	124
50%MAP				Very long	Very long	10	118
45%MAP				Very long	Very long	9	111

Table 1

The number of repetitions used is normally between 3 and 30, and sometimes more, and work intervals may last from a few seconds to several minutes. It is actually the sequencing of these components that determines both the physiological quality called upon (and therefore improved or maintained) and the level of difficulty of the session.

While the number of possible training prescriptions is endless, once certain elements have been decided upon the options for the remaining element(s) are limited, if the session is to be of a reasonable level of difficulty.

To our knowledge, there are no simple models that describe the link between the components of an interval training session and its level of difficulty. Thus, many coaches and practically all athletes find it difficult to add variety to their training programmes, or conveniently assess or monitor a workout's level of difficulty.

Objective

The objective of this article is to present an empirical interval training model that has been developed to help coaches and serious athletes assess how each element of such a training session can vary at a given level of difficulty, and to make it easier to plan workouts and develop training plans.

The model

The proposed empirical interval training model is depicted graphically in Figure 1. It relates the elements of an infinite number of interval training sessions, all of which are of the same level of difficulty.
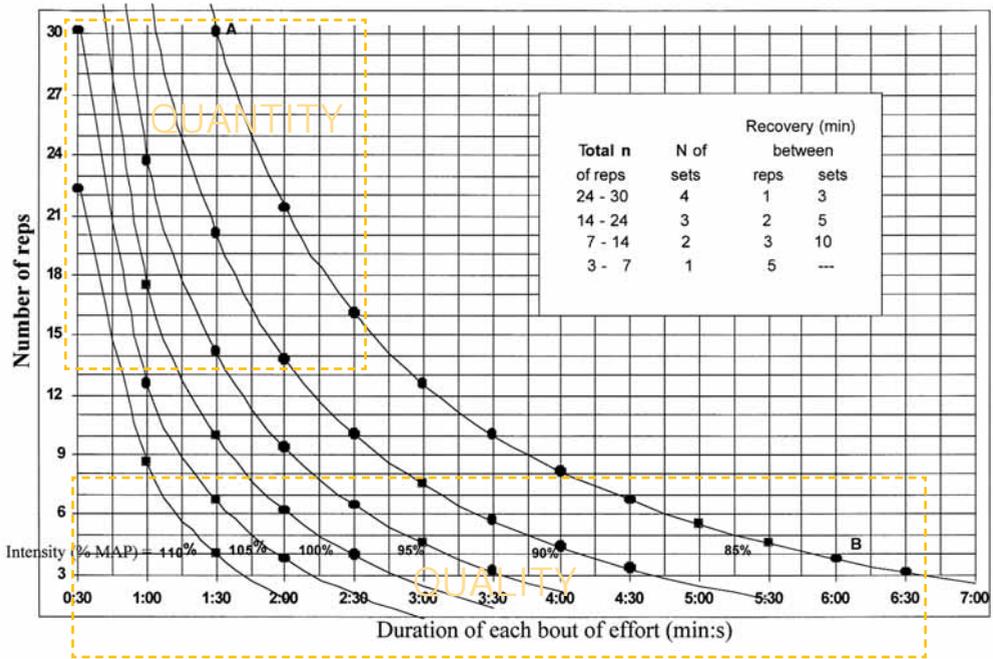
Figure 1 N.B. Points A and B represent sessions that are used as examples in the text.

Each point on the six curves of the graph represents an interval training session (darker points represent sessions in which work intervals are multiples of 0:30 min:s). The duration of work intervals is represented on the x-axis, and the number of repetitions on the y-axis. The six curves correspond to 5% increments of relative intensity, from 85 to 110% of MAP.

As indicated by the table within the graph, we arbitrarily chose to base the three other elements of the session (number of sets, duration of recovery between work intervals and between sets) on the total number of repetitions in the session. We simply attempted to avoid excessively long sessions and to limit the maximum number of repetitions in each set to eight: if there are many repetitions, recovery time is shorter, and the total number of repetitions to be completed will be divided into a greater number of sets. It is assumed that recovery between repetitions and sets occurs at less than 60% of MAP, an easy intensity.

For example, the session represented by point A on the graph consists of 4 sets of 7 to 8 work intervals (for a total of 30 repetitions)

at 85% of MAP, with 1:00 min:s of active recovery between repetitions and 3:00 min:s between sets. The session represented by point B on the graph consists of 1 set of 4 work intervals at 85% of MAP, with an active recovery of 5:00 min:s between repetitions.

Features of the sessions

Some of the features of interval training sessions developed from this model can be described as follows.

1. The nature of the fatigue experienced by the athlete during or after the workout may vary if the session consists of repetitions that are relatively numerous, long or intense. However, the general impression of fatigue will be essentially the same for every session. In fact, all sessions based on the model are perceived as difficult, however, athletes who are very motivated are generally capable of completing them. A one or two day rest period (active or inactive) is commonly required before another "difficult" session.

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2. The content of any session based on the model makes that session useful in terms of developing the key performance factors for a great number of sports. In fact, its intensity will lie between 85 and 110% of MAP — a range that is considered to have an optimum effect on the development of aerobic endurance, MAP and anaerobic capacity, as well as of technical efficiency. Optimising high-intensity training time may also prove to be an important aspect of the motor and psychological preparation of cross country, middle and long distance runners who must compete at power levels that are often higher than those they would automatically use during continuous training sessions.

3. The characteristics of the training sessions based on the model may vary widely: intensity, total number of repetitions (3 to 30), duration of each work interval and total duration of training (15 to 90 minutes, excluding warm-up and cooldown); as a result, the graphic representation of the model may lead the coach or the athlete to consider unexplored forms of interval training, thus enabling them to develop innovative workouts.

4. Sessions consisting of a large number of repetitions at a given intensity will result in a high total training volume at target intensity, while sessions consisting of fewer repetitions will teach the athlete to maintain the target intensity for a longer period of time before recovery. For example, the session represented by point B consists of a total of 24 minutes at 85% of MAP, while the session represented by point A consists of 45 minutes at the same intensity, or almost twice as much time. Therefore, it could be stated that sessions at a given intensity and consisting of a large number of repetitions emphasize quantity (the total volume of work and therefore the amount of high-intensity physiological stimulation are high), while those with few repetitions emphasize quality (the athlete "learns" to

maintain the high intensity for a longer period of time, as he or she will be required to do in competition).

Pedagogical applications of the model

When we presented this model to coaches of high performance athletes, we noted that it facilitates the comprehension of the dynamic link between the various components of an interval training session. As a matter of fact, the model makes it possible to illustrate how to vary one or more of these components to suit the objective, while maintaining a constant level of difficulty. For example, one can use the model to calculate the number of repetitions that must be done at an intensity equal to 95% of MAP, depending on whether the work intervals are 1:00 min:s or 3:30 min:s in length (24 and 3 repetitions, respectively).

Also, it is easy to pinpoint the range in the duration of work intervals for "appropriate" workouts at a given intensity. For example, according to the model, it would not be productive to train at 85% of MAP during work intervals of under 1:30 min:s (the number of repetitions would have to be over 30), or over 6:30 min:s (the number of repetitions would be fewer than 3).

The model can also be used to determine the change that must be made in the number of work intervals of a certain duration when intensity changes. For example, the level of difficulty is exactly the same whether one completes 4 repetitions of 2:00 min:s at 105% of MAP, 14 repetitions at 90% of MAP or 21 repetitions at 85% of MAP.

Using the model to plan training sessions

Coaches and athletes can use the model to design as many different sessions as they wish, at any intensity between 85 and 110% of MAP. As indicated in the figure representing the model, for work intervals that are

multiples of 30 seconds alone, there are 35 different possible workouts at intensities of 85, 90, 95, 100, 105 and 110% of MAP.

By scheduling part of one session based on the model after part of another, sessions can also be developed in which the duration of work intervals and intensity will vary from set to set. For example, based on sessions A and B, the following training session could be developed: 2 sets of 7 or 8 work intervals of 1:30 min:s at 85% of MAP, with respectively 1:00 and 3:00 min:s of recovery, between repetitions and sets, followed by a set of 2 work intervals of 6:00 min:s at 85% of MAP with 5:00 min:s of recovery between repetitions. In this training session, the athlete will have completed half of session A and half of session B.

The coach and the athlete can also use the model to control the level of difficulty of training sessions. A session in which an athlete only completes a fraction of the number of repetitions called for by the model has a level of difficulty below the "maximum" level. For example, completing 5, 6, 7, 8 or 9 work intervals that can be repeated 10 times according to the model corresponds to a 50, 60, 70, 80 or 90% level of difficulty, respectively. However, this is only possible when having a decent measure of the actual power output during work intervals. Such is the case when training on a track, knowing that the O_2 cost of running is approximately 3.5 times the velocity in km/h. For example, running at a 4:00 min/km pace (15 km/h) corresponds to 52.5 mL O_2/kg/min (15 x 3.5), which is 85% of the MAP of a runner who reaches his VO_2 max at 17.6 km/h (61.8 mL O_2/kg/min).

It is interesting to note that when experienced athletes are asked to complete a session based on the model without necessarily being told the target intensity (only the "pattern" of the session, i.e. the number of "work" intervals and the duration of recovery periods between repetitions and between sets), they usually adopt the target intensity automatically. As a matter of fact, those who perform the first work intervals of the session at an intensity that is higher than required by the model will tend to reduce the intensity as they realise that they will not be able to maintain the effort until the end of the session. Conversely, those who start the workout at an intensity that is too low will tend to adjust by increasing the intensity of their work intervals when they realize that the session is not sufficiently taxing. Therefore, during the session, the runner will end up training at an average intensity that is very close to the intensity targeted by the session pattern. Therefore, we only need to mention the session pattern to the runner, without necessarily including the precise target intensity. This can be very helpful, particularly in many sport activities, such as cross country running, in which it is difficult to convey or assess intensity of work.

For all practical purposes, the desired physiological demand will likely be achieved by specifying only the session pattern because the athlete will train at an intensity that will not differ markedly from the target intensity.

It should be noted that target heart rate cannot be used as a convenient way of conveying or monitoring intensity of work intervals. This is clearly true in the case of all sessions at supra-maximal intensity, i.e. above 100% of MAP. Even in sessions requiring effort at sub-maximal intensity (less than 100% of MAP), heart rate does not reach a plateau quickly enough for this parameter to really help the athlete achieve the desired intensity of work.

Using the model to plan the training programme

The model does not impose an approach to the development of a long-term training programme, but it enables the coach or the athlete to develop a personal approach. One can set a progression to follow during a phase of the training programme by "numbering" the sessions in the order in which they are to be completed. The possibilities are endless, but Table 2 shows three progression modes

Type of Progression	Description	Justification
Intensity progressively increased	All sessions at 85% of MAP, followed by sessions at 90% of MAP and so on through the season, until 110% of MAP is reached.	Facilitates metabolic, motor, musculoskeletal and psychological adaptation to sub-maximal and maximal intensities before the athlete progresses to supra-maximal intensities.
From Quantity to Quality	Sessions consisting of numerous repetitions at the beginning of the season, followed by sessions consisting of fewer and fewer repetitions, regardless of intensity.	Maximises total work time at target intensities at the beginning of the program (emphasis on quantity); the athlete gradually learns to maintain intensity for a long period of time before resting (emphasis on quality).
Duration of the training sessions progressively increased	From the shortest to the longest session, regardless of intensity.	Gradually prepares the athlete for longer and longer training sessions.

Table 2

that coaches (who were asked to complete exercises on applications of the model) suggested on their own.

Thus, coaches or athletes can establish progressions based on their individual approaches, while controlling the level of difficulty of sessions throughout the entire season. Of course, a progression in the level of difficulty of the sessions can also be set up, as previously described, by having athletes complete a number of repetitions that is a fraction of the "maximum" number of repetitions called for by the model.

Validity and limitations of the model

Any approach to the planning of training is difficult to validate because it requires, the rigorous monitoring of parameters that are subject to fluctuation within a large sample group of athletes at various levels. The model presented here is no exception.

Nevertheless, to assess its validity, we asked an athlete to complete, in the laboratory, 31 sessions based on the model. He noted that while the nature of the fatigue experienced during and after each session varied according to the content of the workout, the general and subjective impression of overall fatigue was essentially the same for every session.

Therefore, no systematic bias was identified. Whether the session was short or long, whether it was completed at a high or very high intensity, and whether the total number of repetitions was large or small, the athlete always needed strong motivation in order to complete any of the 31 training sessions derived from the model. He stated that, in every case, the one or two day period of active or inactive rest that he was given seemed necessary in order for him to be able to complete the next "difficult" session. During the three

months of the experiment, the MAP of this athlete rose by 20 watts per month (during which time he completed approximately ten sessions based on the model, with one to three days of active rest between each session), increasing from 380 to 440 watts, which represent equivalent VO_2 max values of 60 and 68 mL O_2/kg/min, respectively.

Although a single case is not a statistically valid sample, it is interesting to note that the athlete did not consider any one type of session to be more difficult than another.

Although the model has not actually been validated, comments by coaches and athletes who use it indicate that it has useful pedagogical and practical applications in terms of organising sessions and developing long-term training plans.

This version of the model cannot be used to assess the effect of changing the duration of recovery between repetitions and sets. However, experienced coaches know that if duration and intensity of recovery vary within a reasonable range — for example, plus or minus 20% — the number of repetitions that can be completed before a given level of fatigue is reached remains relatively constant.

The model does not apply to training sessions that consist of work intervals of under 30 seconds; this is a significant shortcoming, which may be corrected in a subsequent version. As a matter of fact, it is well known that short-interval training has a marked effect on the development of MAP and anaerobic capacity. Whether or not it is possible to generate "reasonable" session content by developing projections of the model's formulas for intensities above 110% of MAP and durations shorter than 30 seconds remains to be tested.

Conclusion

In conclusion, while empirically based and not rigorously validated, the proposed model of the dynamic link between the components of an interval training session seems to have practical applications on a pedagogical level and in terms of planning sessions and developing training programmes in many sports, such as cross country, middle and long distance running, in which MAP, aerobic endurance and anaerobic capacity are key performance factors.

For more information regarding this paper please do not hesitate to contact Dr. Guy Thibault at guy.thibault@sls.gouv.qc.ca.

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