Power-based training levels

BY CHARLES HOWE

Over the past six months, this column has covered general aspects and phases of preparation for endurance cyclists – training "macrostructure," as it were. As spring approaches and riding grows more specific (tailored to a particular goal), it is necessary to discuss the "microstructure" of training somewhat, with a system that classifies workouts according to the nature of the imposed exercise stress and the adaptations achieved.

Point of reference

Numerous schemes similar to the one below (Table 1) have been proposed elsewhere down through the years, but all share two things in common: a means of quantifying absolute exercise intensity, such as power or speed, and a point relative to which intensity can be gauged. For the former, speed (or pace) works quite well for activities like running, skating, swimming, etc., but for road cyclists, who encounter ever-changing resistance forces of terrain and wind (not to mention much larger variations in effort), speed turns out to be a much less reliable measure of energy output. The advent of affordable on-bike power-measuring systems in recent years has solved this dilemma, allowing accurate measurement of the true stress load imposed.

The most reliable power-measuring system is meaningless, however, without a way to interpret the data it generates. Oftentimes, training intensity is described in relation to some maximal value, but the choice here is lactate threshold (LT). That may sound like an intimidating physiological concept, but LT can be illustrated with a simple comparison: imagine two cars, each having identical aerodynamics (i.e., the same body), equal weight, and equally powerful engines, but in car #1, when you try to sustain more than 80% of maximum horsepower for more than a few minutes, a sort of governor kicks in that makes the engine throttle back until various conditions return to a particular operating range. On the other hand, if the governor in car #2 doesn't engage until 90% of maximum, it clearly can be run at a higher output for an extended period of time.

The horsepower-governor analogy helps illustrate the relationship between the central and peripheral determinants of endurance performance, i.e., maximal oxygen uptake volume (VO_{2max}), and VO_2 at LT, respectively:

1. the first sets the upper limit of steady-state (aerobic) energy production, and is determined primarily by the ability of the heart to pump oxygen-carrying blood to the working muscles
2. the latter determines the percentage of VO_{2max} that can be utilized for an extended period (3 minutes or longer), and correlates with the density of mitochondria (the locus of aerobic energy production) within the working muscles, as well as the extent of capillarization present, two adaptations that depend largely on years of sport-specific endurance training at an adequate intensity

VO_{2max} is determined in a lab by analyzing expired gasses during a graded ("ramped") exercise test on a calibrated ergometer cycle, wherein increasing workloads are imposed in a specific, incremental protocol until exhaustion is reached. LT is determined along the way, prior to exhaustion, through analysis of blood samples.

So the practical importance of LT in setting training levels is clear, but does it have to be determined in a lab? All too often, athletes seem compelled to make a cross-state pilgrimage to be tested and have training levels assigned in the same way a guru bestows a mantra. Fortunately, there is a simple and practical alternative means to determine essentially the same thing: average power from a 40-60 minute solo effort on the road, or "functional threshold power" (FTP), correlates very closely with lab-derived results; be sure you are adequately rested and recovered beforehand, use a flat course, and avoid extremes of wind and temperature. Such a functional test saves time, reduces carbon emissions, and (best of all) serves as a workout, three things that cannot be said of a lab test.

The resulting levels

Energy for muscular work is either produced aerobically, via biochemical pathways that utilize oxygen, or else anaerobically, i.e., without oxygen, though it is important to realize that aerobic metabolism never shuts down, always providing the background against which anaerobic energy output rises and falls. The amount of work that can be performed aerobically is virtually unlimited, but it occurs at a slower rate than the large and rapid bursts of output from anaerobic sources, which are in turn are limited by the length of time they can be sustained; LT is the dividing region between the two processes, above which lactic acidosis begins to inhibits muscular contraction, with the familiar symptoms of rapid breathing and a burning sensation concentrated in the thighs. The higher LT can be raised, the more the energy can be produced aerobically, allowing limited anaerobic reserves to be spared.

Lactate threshold may also be used to roughly divide the training levels specified below, with Levels 1-4 being overwhelmingly aerobic. Contrary the occasionally fashionable view, there are no special benefits to lower-intensity training; the adaptations from Levels 2-4 are all the same, they simply occur in varying degrees, i.e., more quickly as intensity approaches LT (Table 2). Thus, the working stiff's 2 × 20 minute threshold repeats produce the same result as the Euro Pro's 6-hour rides but the latter yield more total adaptation and improvement in LT, simply because the amount of training time is so much greater, thereby overcoming the slower rate of training effect. In other words, it's not the lower intensity of long rides, in and of itself, that makes the difference – it's the duration. Again, VO_2 at LT determines the basic level of endurance performance, and the mechanisms by which it is raised are increases in the capillaries and mitochondria of the working muscles, which allow more oxygen to be delivered through the blood for greater aerobic energy production. These adaptations come from imposing consistent aerobic demand on a long-term basis – or in other words, lots of training at Levels 2, 3, and 4. I was shocked to see a purported expert claim recently that "overloading muscle cells with lactic acid causes mitochondria . . . to increase in relative size and number." In fact, lactic acidosis *inhibits* muscular contraction, thereby limiting and interfering with aerobic training, so it should generally be avoided until aerobic development is as complete as possible.

Level 5 is still mostly aerobic, with a small-but-significant anaerobic component, and workouts at this level – typically 5-6 repetitions lasting 5 minutes each, with 3-5 minutes recovery in between – can be used once weekly in the last 5 weeks of a base period to 'peak' maximal aerobic capacity, which raises FTP as well.

Levels 6 and 7 are both heavily anaerobic, but there is a radical underlying difference between them: so long as the latter remain under 15 seconds and are followed by complete recovery (5 minutes easy spinning), they do not result in significant lactic acidosis, and can be carried out most anytime throughout the training year, as deemed appropriate. On the other hand, Level 6 training, most typically in the form of a 10 × 1 minute interval workout performed three times a week for 2-3 weeks, should be scheduled only after the aerobic base training period is complete, as a sort of "icing on the cake."

How hard it is, how hard it feels

With adequate rest and proper diet between workouts, power output is quite reproducible (consistent) from day-to-day, and is the most useful gauge of the training stress (stimulus) being applied, or how hard an effort truly is. Even so, the resulting strain (response) experienced by the body, or how hard an effort feels, must be considered too. This is best described with the revised 10-point scale of perceived exertion (PE) first developed by Swiss psychologist Gunnar Borg in the 1970s (Table 3). Heart rate (HR) is frequently used as a proxy for the level of strain experienced by the body, and although it associates well enough with power on an ergometer or most any stationary trainer, HR increases, or "drifts" upward as exercise wears on, even under controlled conditions and with a constant load. Outdoors, the correlation is lower still, even under the best conditions, and only gets worse as factors including pace, terrain, heat, hydration status, etc., take effect.

PE, on the other hand, is the product of eons of human evolution and reflects more physiological variables than HR, especially the most important among them, namely, blood lactate levels. A fine sense of PE, coupled with power data, is essential to optimal energy distribution and consistent, productive Level 2-4 workouts, which as part of a periodized, progressively overloaded training plan, allow aerobic development to continue almost indefinitely. As the late Arthur Lydiard often said, "*Train*, don't *strain*," or, put another way, *work*, don't *suffer*. While this approach requires some discipline and restraint, especially in the initial stages of each ride, with just a little conscious effort it can soon become so habituated that anything else feels wrong.

REFERENCE

Jubrias, S.A., G.J. Crowther, E.G. Shankland, R.K. Gronka, and K.E. Conley. Acidosis inhibits oxidative phosphorylation in contracting human skeletal muscle *in vivo*. *Journal of Applied Physiology* 533.2:589-599, 2003.

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Table 1. Power-based training levels.

INTENSITY	AVG. POWER*	AVG. HR*	PE	DESCRIPTION	TYPICAL WORKOUT
Level 1 *Active recovery*	≤55%	≤68%	<2	"Easy spinning" or "light pedal pressure," i.e., very low level exercise; too low in and of itself to induce significant physiological adaptations. Minimal sensation of leg effort/fatigue. Requires no concentration to maintain pace, continuous conversation possible. Typically used for "active recovery" after strenuous training days (or races), between interval efforts, or for socializing.	40 – 60 minutes
Level 2 *Endurance*	56-75%	69-83%	2-3	"All day" pace, or classic "long slow distance" (LSD) training (note that "slow" is in relation to the very high intensity, interval-centered training programs that were popular when the term was coined in the 1970s). Sensation of leg effort/fatigue generally low, but may periodically rise to higher levels (e.g., when climbing). Concentration generally required to maintain effort only at highest end of range and/or during very long rides. Breathing more regular than Level 1, but continuous conversation still possible. Frequent (daily) training sessions of moderate duration (i.e., 2 hours) at Level 2 possible (provided dietary carbohydrate intake is adequate), but complete recovery from longer workouts may take more than 24 hours.	3+ hours
Level 3 *Tempo*	76-90%	84-94%	3-4	Typical intensity 'spirited' group ride or briskly moving paceline. More frequent/greater sensation of leg effort/fatigue than at Level 2. Requires concentration to maintain alone, especially at upper end of range, to prevent effort from falling back to Level 2. Breathing deeper and more rhythmic than Level 2, such that any conversation must be somewhat or very halting, but not as difficult as at Level 4. Recovery from Level 3 training sessions more difficult than after Level 2 workouts, but consecutive days of Level 3 training still possible if duration is not excessive and dietary carbohydrate intake is sufficient.	1.5 – 3 hours

INTENSITY	AVG. POWER*	AVG. HR*	PE	DESCRIPTION	TYPICAL WORKOUT
Level 4 *Lactate threshold*	90-105%	95-105%	4-5	Just below to just above FTP, taking into account duration, current fitness, environmental conditions, etc. Essentially continuous sensation of moderate or even greater leg effort/fatigue. Continuous conversation difficult at best, due to depth and frequency of breathing. Effort high enough that continuous cycling at this level is mentally taxing – therefore typically performed in training as multiple 'repeats' of 15-30 minutes (totaling 30-60 minutes). Recovery between efforts need be no more than needed for a mental break or to turn around. While consecutive days of training at Level 4 may be possible, such workouts should, in general, be performed only when sufficiently rested/ recovered from prior training, so as to be able to maintain intensity.	2 x 20 minutes
Level 5 *Maximal aerobic power*	106-120%	>106%	6-7	Longer intervals (3-8 minute, with 2:30-5:00 recovery) meant to raise VO_{2max}. Strong to severe sensations of leg effort/ fatigue, such that completion of more than 30-40 minutes total training time is difficult at best. Conversation not possible due to often 'ragged' breathing. Should be attempted only when adequately recovered from prior training – consecutive days of Level 5 work generally not desirable, even if possible.	5-6 x 5 minutes
Level 6 *Anaerobic capacity*	≥121%	n/a	>7	Short (30 seconds – 3 minutes), high-intensity intervals designed to increase anaerobic capacity. Nearly complete recovery in between. Heart rate not useful as guide to intensity due to non-steady-state nature of effort. Severe sensation of leg effort/fatigue, and conversation impossible. Consecutive days of Level 6 training rarely attempted.	8-15 x 1 minute
Level 7 *Neuromuscular power*	n/a	n/a	**	Very short (<25 seconds), very high intensity efforts (e.g., jumps, standing starts, short sprints) that generally place greater stress on the musculoskeletal rather than metabolic systems. Complete recovery in between efforts. Power useful as guide, but only in reference to prior similar efforts, not TT pace.	5 x 15 seconds (2-3 sets)
*As % of FTP, defined as average in a 60 minute time trial. **Maximal					

Table 2. Summary of training adaptations.

EXPECTED PHYSIOLOGICAL/ PERFORMANCE ADAPTATIONS	RELATIVE BENEFIT BY TRAINING LEVEL					
	2	3	4	5	6	7
Increased plasma volume	✓	✓✓	✓✓✓	✓✓✓✓	✓	
Increased muscle mitochondrial enzymes	✓✓	✓✓✓	✓✓✓✓	✓✓	✓	
Increased lactate threshold	✓✓	✓✓✓	✓✓✓✓	✓✓	✓	
Increased muscle glycogen storage	✓✓	✓✓✓✓	✓✓✓	✓✓	✓	
Hypertrophy of slow twitch muscle fibers	✓	✓✓	✓✓	✓✓✓	✓	
Increased muscle capillarization	✓	✓✓	✓✓	✓✓✓	✓	
Interconversion of fast twitch muscle fibers (type IIb → type IIa)	✓✓	✓✓✓	✓✓✓	✓✓	✓	
Increased stroke volume/maximal cardiac output	✓	✓✓	✓✓✓	✓✓✓✓	✓	
Increased VO_{2max}	✓	✓✓	✓✓✓	✓✓✓✓	✓	
Increased muscle high energy phosphate (ATP/PCr) stores					✓	✓✓
Increased anaerobic capacity ("lactate tolerance")				✓	✓✓✓	✓
Hypertrophy of fast twitch fibers					✓	✓✓
Increased neuromuscular power					✓	✓✓✓

Note: this table is meant to indicate the relative 'potency' of each training level, i.e., the extent to which training at a particular intensity *for a given period of time* is expected to induce the listed adaptations, however, there will always be a trade-off between training intensity and training volume, which is unaccounted for here. With respect to increasing resting glycogen stores, for instance, this means that a whole lot (whatever that is) of training at Level 2 might be just as, if not more effective than much less training at, say, Level 3.

Table 3. 10 point perceived exertion scale.

LEVEL	SENSATION
0	Nothing at all
½	Extremely weak (just noticeable)
1	Very weak
2	Weak (light)
3	Moderate
4	Somewhat strong
5	Strong (heavy)
6	
7	Very strong
8	
9	
10	Extremely strong
**	Maximal