Power-based training levels

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In developing the following schema, I have drawn from a number of sources, including Peter Janssen's *Lactate Threshold Training*, *The Cyclist's Training Bible*, by Joe Friel, and the British Cycling Federation's training guidelines (developed by Peter Keen), in addition to my own background in exercise physiology and experience of training and racing with a Power Tap hub since 1999. I would also like to recognize all the people who responded to my initial request for power data, as that has helped me to verify and refine the system. I'll begin by describing the various 'levels' in the system first, followed by a table of the adaptations induced by each, then move to a discussion of some of the details.

INTENSITY	AVG. POWER*	AVG. HR*	PE	DESCRIPTION	TYPICAL WORKOUT
Level 1 *Active recuperation*	≤55%	≤68%	<2	"Easy spinning" or "light pedal pressure," i.e., very low level exercise, so as to minimize muscular force requirements; too low in and of itself to induce significant physiological adaptations. Minimal sensation of leg effort/fatigue. Requires no concentration to maintain pace, and continuous conversation possible. Typically used for "active recuperation" after strenuous training days (or races), between interval efforts, or for socializing.	30-75 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 is more regular than at Level 1, but continuous conversation is 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 recuperation from longer workouts may take more than 24 hours.	2-5 hours
Level 3 *Tempo*	76-90%	84-94%	3-4	Typical intensity of fartlek workout, '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. Recuperation 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 TT effort, 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 sufficiently high that continuous cycling at this level is mentally taxing – therefore typically performed in training as multiple 'repeats,' 'modules,' or 'blocks' of 15-30 minutes duration (totaling 30-60 minutes). Recovery between efforts need be no longer than required 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 × 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 × 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.	8-10 × 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.	6 × 15 seconds (3 sets)
*As % of average in a 60 minute time trial. **Maximal					

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

Magnitude of adaptations of by training level.

EXPECTED PHYSIOLOGICAL/ PERFORMANCE ADAPTATIONS	**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.

DISCUSSION

Average power during a 1 hour time trial, or functional threshold power (FTP), provides a logical basis for training levels since it correlates very highly with power at lactate threshold, the most important physiological determinant of endurance cycling performance, integrating VO_{2max}, the percentage of it that can be sustained, and cycling efficiency (although, if you define LT as a 1 mmol/L increase in blood lactate over the baseline observed during low-intensity exercise, the corresponding wattage will be some 10-20% lower than FTP). Indeed, beyond the first few seconds of exercise, the entire power-duration performance curve can be described quite closely using just two mathematical parameters, representing anaerobic capacity and power at lactate threshold, respectively. While shorter efforts might be more convenient, 60 minutes was chosen because it corresponds roughly to the former standard TT distance of 40 km, and because it is only slightly less than that generated during shorter TTs. In theory, one could derive specific correction factors to be used with data during shorter TTs (e.g., power during a ~20 minute TT will be ~1.05 times that of 60 minutes) in order to fit such data into the system, but given individual variation in the exact shape of the power-duration curve, day-to-day variability in performance, and the breadth of the specified power levels, this may only convey a false sense of precision. Along somewhat the same lines, one could base a system on laboratory-derived measures, such as lactate threshold itself, but relatively few people have access to such measurements, as opposed to simply going out and measuring their own power during a TT. Conversely, one could dispense with using one single 'anchor' measurement, and simply reference all workouts back to the maximum power that an individual can generate for that duration (i.e., Friel's 'critical power paradigm'), however, such an approach requires much more testing than simply using average TT power, while providing little if any practical advantage, in my opinion.

There is about a 3-5% tolerance to each training level, e.g., if your Level 1 recovery rides are up to 58-60% instead of <55% of your "true" threshold (60 minute) power, because you have estimated the latter from a shorter test, it really will not make any difference. Any more than 3-5%, though, and things do begin to change significantly, meaning that the percentages used to set the training levels would have to be adjusted, from which arises the question, "what is the shortest TT during which your power will be no more than 3-5% greater than what you could sustain for a 60 minutes?" The answer will vary somewhat between individuals. For instance, my own power for a ~20 minute TT is only about 4% higher than over 60 minutes, so it would work pretty well for me personally, however, my power-duration curve is "flatter" than the vast majority of people out there; one study, for example, found that average power during a 20 km (not 20 minute) TT was 107% of that during a 60 minute TT. Consequently, I am leery of basing training levels (using my system, without any adjustments) on the results from anything shorter than a 30 minute effort.

Determining the appropriate number of levels is somewhat arbitrary, since the physiological responses to exercise really fall on a continuum, with one intensity domain blending into the next. In other words, there really is no clear distinction between high Level 3 and low Level 4, it is all just shades of grey. A compromise was therefore struck between defining more levels, to better reflect this fact, and fewer, for simplicity's sake. The seven levels specified were considered the minimum needed to adequately describe the different types of training required to meet the demands of competitive cycling, so the range within each is somewhat broad, but this should not be a major disadvantage, for several reasons. First, there is obviously an inverse relationship between a given power output and how long it can be sustained, thus, it is axiomatic that shorter training sessions or efforts will be conducted at the higher end of a given range, whereas longer sessions or efforts will fall towards the middle or lower end of a given range. Second, since power is a more precise indicator of exercise intensity than, for instance, heart rate, workouts should still be adequately controlled despite the seemingly large range in power within each level. Finally, as with all training systems, exercise prescriptions should be individualized, in this case taking into account the power the athlete has generated in previous similar or identical workouts . . . the primary reference, therefore, is not to the system itself, but to the athlete's own unique (and current) ability. In this regard, the present classification scheme should be viewed primarily as an overall framework, not a detailed plan.

The suggested heart rate ranges must be considered as imprecise, because of individual differences in the positive y-intercept of the power-heart rate relationship. That is, even when power is zero, heart rate is not, with differences between individual in this ‘zero power’ (not resting) heart rate significantly influencing the percentage of average 60 minute TT heart rate corresponding to any given power output. Because of this, I do not believe it is really useful to try to derive power ranges from heart rate ranges (as Friel’s initial attempt to do so readily shows). Expressing heart rate as a percentage of the range from that at zero power (derived by back-extrapolation of the linear power-heart rate relationship) to that at FTP – akin to the Karvonen formula for heart rate reserve – corrects for this individual effect and allows you to more precisely specify the levels based on heart rate, however, I rejected this approach as simply being too complex, especially given that this is a power-based system. Nonetheless, I have derived guidelines for heart rate (as well as perceived exertion) from power data, which can be used along with power to help guide training.

Guideline values given below for perceived exertion are from Borg’s 10 point category-ratio scale, not the original 20-point scale that is probably more familiar to most people, because the category-ratio scale explicitly recognizes the non-linear response of many physiological variables (e.g., blood and muscle lactate), and thus provides a better indicator of overall effort. Since perceived exertion increases over time, even at a constant exercise intensity (power), the suggested values or ranges are for relatively early in a training session or series of intervals.

While this system is based on the average power during a workout or interval effort, consideration must also be given to the distribution of power within a ride. For example, average power during mass start races typically falls within the range defined as Level 3 (‘tempo’), but races are usually more stressful due to the greater variability (and therefore higher peaks) in power. Similarly, due to soft-pedaling/coasting down hills, the same average power achieved during a hilly (or even mountainous) ride will not reflect the same stress as an equal average power achieved during a completely flat workout. To some extent, this variability is taken into account in defining the various levels, especially Levels 2 and 3 (training at the higher levels is likely to be much more structured, thus tending to limit variations in power), and can be accounted for more precisely using Normalized Power™. Nonetheless, a workout consisting of, say, 30 minutes at Level 1 (as warm-up in transit from an urbanized area), 60 minutes at Level 3, and another 30 minutes at Level 1 (as warm down) would best be described as a tempo training session, even though overall average power might fall within Level 2 (‘endurance’).

A final caveat: defining various training ‘levels’ is only the first step in developing a training plan; what matters as well is the distribution of training time or effort devoted to each level. Discussion of such follows shortly, but two points I wish to emphasize are: 1) I believe that training should be highly individualized, to account for each athlete’s unique abilities, goals, and state of development (e.g., age, training background), and 2) compared to some, I tend to place more value in training at Levels 2, 3, and 4 – indeed, what many consider to be ‘junk training.’ In that regard, my philosophy apparently parallels that of Peter Keen, or at least how his ideas are reflected in British Cycling Federation training guidelines.