There are three basic ways to determine intensity, each with it's own particular caveats. The most accurate way to measure intensity on a bike at any given moment is through the measurement of power. Power is the product of force and speed of movement, with speed of movement in this case being cadence. Power measurement provides cyclists with instant, precise feedback, and their recording/downloading capabilities allow for thorough post-ride analysis of training and racing efforts. Unfortunately, powermeters are also relatively expensive, add a small amount of weight to a bike, and in some cases limit equipment choices. Still, many riders who rely on powermeters use them in all training and racing situations.

A differentiator of using power as one's intensity measure is that it also provides a **performance** measure at the same time. This is something that is much more limited when using Heart Rate (HR) or Perceived Exertion (PE). Getting performance feedback on a daily basis from one's powermeter enables athletes and coaches alike to both implement and monitor a training program with a much greater level of precision. With adequate analytical skills and tools, overall workload can be quantified very precisely, small improvements can be recognized instantly, and as a result training plans can be changed in accordance with this information.

Another way to monitor one's level of intensity is by measurement of HR. HR monitors have been commonplace in cycling, as well as other endurance sports, since the late 1980's. The tools themselves are relatively cheap, reliable, lightweight, and come with a plethora of available features. There is a relatively large volume of research and experiential data on HR-based training, due to its relatively longer time in practice and larger number of practitioners compared with power-based training.

The caveats when relying on HR measurement are many. The relatively slow response time of HR to changes in intensity (half life on the order of 30 seconds) makes executing relatively short intervals (5 minutes and less) quite difficult if using HR to pace them. Additionally, HR responsiveness varies between individuals, as well as day to day for the same individual. A list of some of the factors affecting HR includes heat, humidity, relative fatigue level, cadence, "burstiness" or variability of power being produced, hydration level, and general level of excitement. Due to this list of factors, monitoring HR is a less precise way of measuring intensity than monitoring power. Additional factors such as cardiac drift, the tendency for HR to gradually rise over time given constant power, make monitoring HR a quite complex subject. To summarize, it is impossible to accurately quantify all the various factors that may be impacting HR at any given moment in such a way that the number can be trusted as being a very reliable measure of intensity on its own. HR monitoring only measures one element in a complex system (the human body), and as such is cannot be assumed to **define** whole-body stress; it is only an **indicator**.

Despite all its shortcomings however, HR can be utilized as an effective qualitative tool in monitoring exertion. It is more challenging than using power due to all the factors listed above, and it's not a measure of performance like power, but it still gives a good sense of how hard one is working if implemented intelligently. Indeed, a great number of competitive cyclists still use HR as their primary measure of intensity,-- certainly many times more than use power measurement. Many races have been won by riders who have never trained with or otherwise used a powermeter, and executing a well-designed training plan without a powermeter is certainly far from impossible.

Although Perceived Exertion (PE) is listed here as the third possible measure of intensity, it is wrong to think that it might be possible to train without it. One thing that cannot be avoided when riding, whether racing or training, is thinking about how one's body feels at any given moment, and in some cases how much it hurts. It does no good to prescribe an interval at a certain power or HR zone if the rider cannot complete the duration of the interval due to the negative feedback from their body. Whether riding with or without power or HR measurement, using PE to monitor one's output is not only a perfectly good measure of intensity, it is unavoidable.

Being able to sense how hard one is going, and in turn expend energy accordingly such that one is able to reach some milestone (the top of a climb, end of a time trial, end of an interval, etc) is an intrinsic skill that all riders cultivate to some extent. In fact, when all the technology of powermeters and HR monitors break down, it's important to still be able to sense at any moment what one's level of exertion is. Experienced riders can often tell within a few watts or a few beats what their power or HR are at any given moment. While the tools make structured training easier by allowing insight into the intensity level, they are by no means required. The human brain and the accompanying feedback system (Central Nervous System, or CNS) that comes with it are literally priceless.

Some established coaches prefer riders not use any power or HR feedback devices in competition, as they feel the psychological ramifications of seeing that feedback may limit the athlete to merely mimic historical performance, rather than breaking through to set a new benchmark. This is particularly notable in the use of HR monitors, where a rider may be pacing an effort perfectly within their capabilities on a given day, but glancing down at the HRM and seeing an abnormally high or low number will make them believe they are going too hard/easy, and thus stray from what was an ideal effort for them. Likewise, with a powermeter riders may tend to limit themselves to an effort they know they can do from experience, and preclude the possibility of higher performance in competition. Examples of this are pacing a time trial at too low a power, or pacing oneself up a long climb in a road race at too low a power, and losing contact with the pack as a result.

Some strategies to avoid these mistakes include using power or HR monitors to record data for later review, but taping over the display so as not to be influenced by the feedback from it during the race or interval. Analyzing the resultant data after the fact, and comparing it with one's perception of the event leads in turn to a greater understanding of one's physical limits. In nearly all cases, riders are able to surpass any training benchmark they have previously set when performing in a competitive situation. Even researchers in the field of performance testing for sport, who devise various ways to entice athletes to perform at a competitive rather than a training level, recognize this fact. These enticements may include simply holding a "competition" to see who can pedal the longest on an ergometer at a certain workload, who can produce the most watts per bodyweight for a specified period of time, and so on.

What is “Threshold”?

Intensity zones have always been anchored on the concept of “threshold”. The concept of “functional threshold” does the best job of incorporating VO2 Max, lactate threshold, as well as endurance into one anchor point upon which all zones are based. Functional threshold is defined as the power or HR that can be sustained for roughly 1 hour in a competitive situation. Examples of how to determine this level would be a competitive 40k TT (average power and average HR), a hard 1 hour criterium (*normalized** power and HR), or a 1 hour cyclo-cross race (HR). Due to the various definitions used in lab settings for Lactate Threshold (LT), this method provides a better functional estimate of the **sustainable** performance of an individual. While measuring lactate levels using blood samples in a lab test is the most precise way of determining an athlete’s power at LT, very few individuals have access to such measurements on a routine basis. Additionally, there are various definitions of LT used in various labs for various reasons. Some tests will define it as a set concentration of blood lactate, with LT being defined as a 1 mmol/L increase in blood lactate over exercise baseline, or in some cases 4mM (Onset of Blood Lactate Accumulation, or OBLA). While this ensures consistency in lab methods for research purposes, in truth some riders may be able to sustain a higher or lower lactate concentration than any of these values, and in fact even for the same individual the ability to tolerate and clear lactate at a certain concentration will vary over a period of days. The functional threshold definition that zones are based on is closest to the Maximal Lactate Steady State (MLSS) definition of LT, which represents the highest exercise intensity that can be maintained without a continual increase in blood lactate.

While all these methods are highly correlated, due to the various definitions of LT it is important to know the details behind the use of the term “threshold”, and to that these training programs are based on the resultant zones.

* - Normalized power refers to a process developed by Dr. Andrew Coggan which better measures of the true physiological demands of training session that involve particularly variable power - in essence, it is an estimate of the power that one could have maintained for the same physiological "cost" if power output had been perfectly steady rather than variable. As an example, it is common for average power to be lower during criteriums than during equally-difficult road races, simply because of the time spent soft-pedaling or coasting through sharp turns. Assuming that they are about the same duration, however, the normalized power for both types of events will generally be very similar, reflecting their equivalent intensity.

Table of Power Based Training Zones

Name	% of Threshold Power
1. Recovery	0-55%
2. Easy	56-75%
3. Tempo	76-90%
4. Threshold	91-105%
5. VO2 Max	106-120%
6. Submax	121+%
7. Max	Maximal

* Power based training zones are taken from those developed by Dr. Andrew Coggan, Ph.D.

Table of Heart Rate Training Zones

Name	% of Threshold HR	% of Max HR
1. Recovery	0-70%	0-60%
2. Easy	71-80%	61-72%
3. Tempo	81-90%	73-80%
4. Threshold	91-100%	84-90%
5. VO2 Max	100+%	90+%
6. Submax	100+%	90+%
7. Max	-	-

Table of Perceived Exertion Training Zones

Name	Description*
1. Recovery	<7 on this scale, can whistle or sing
2. Easy	8-9, able to converse
3. Tempo	10-13, talking in complete sentences is more difficult.
4. Threshold	14 – 16, more than a few words at a time difficult, labored breathing - especially near the end of the efforts.
5. VO2 Max	>17. Very hard breathing.
6. Submax	20. Maximal
7. Max	20. Maximal

* Numerical descriptions taken from Borg Scale of Perceived Exertion.

L1/Zone 1/ Recovery

The heart rate range for the recovery zone is below 70% of threshold HR, or below 60% of your maximum heart rate. Power range is below 55% of threshold power. Purely aerobic, glycogen, fat and adenosine triphosphate (ATP) are the primary fuel sources. In this zone, residual lactic acid is cleared from the blood quickly and minimal new lactate is produced, allowing recovery to take place. Blood lactate is typically below 1 millimole/liter of blood. A millimole/liter (mM/L) measurement is simply a way to describe the concentration of lactate in the blood.

This is not a training zone; it is a recovery zone, and you'll notice that your training program doesn't account for it when determining ride times. Anything in this zone will be above and beyond the numbers you get "credit" for, but will still be an important part of an interval workout.

L2/Zone 2/ Easy/Endurance

The range for easy is from 71-80% of threshold HR, or 61-72% of max HR. From a power perspective, this zone is between 56% and 75% of threshold power. This is the basic endurance zone, the first aerobic capacity training zone. Anything easier than this is recovery, not training. Fuel sources are the same as the recovery zone, but lactate levels are generally higher. Rides that focus primarily on this zone may range from 2 – 7 hours, depending on the background and needs of the rider. These rides are designed to burn fat, increases mitochondrial density, and increase blood plasma volume.

L3/Zone 3/ Tempo

The range for tempo is from 81-90% of threshold HR, or 73-80% of max HR. From a power perspective, this zone is between 76% and 90% of threshold power. Also known as extensive duration, or in some cases tempo. The emphasis here is still on endurance, although intensive rides in this zone will also have a positive effect on threshold power, and a smaller positive effect on VO2 Max. Fuel sources are the same as in as previous zones, though fat begins to be used less, and glycogen becomes the primary fuel source.

Interval lengths for this zone can vary from 15-180 minutes, depending on the purpose of the interval, and the ride in general. A straight “tempo ride” for the purpose of building endurance will typically consist of a single uninterrupted (except for necessities such as traffic signals and stop signs) interval that approaches the maximal time they can handle at this intensity. For newer riders early in a training program, that might be as little as 30-45 minutes, while it is extremely rare to find a rider who can ride continuously in this zone in excess of 3 hours. There are other places the tempo zone is used, in more moderate amounts. On a sprint workout day, for instance, often a small amount of tempo is called for in order to avoid excessive detraining of the aerobic system on a day where neuromuscular training is the primary focus.

The intensity of this zone is comparable to a rolling tempo in a road race, or sitting in during an easy criterium. You can still speak in full sentences, but are somewhat uncomfortable, particularly as you get to the second half of a workout. Expected physiological benefits from training in this zone include increased mitochondrial density, increased plasma volume, increased muscular endurance (time to fatigue), and increased muscle glycogen storage.

L4Zone 4/Threshold

Also known as intensive duration. L4 is the threshold training zone, and the target is within 10% of one's threshold power or HR. The range is from 91-100% of threshold HR, or 84-90% of max HR. From a power perspective, this zone is between 91% and 105% of threshold power. This power level, when normalized for weight, is probably the single most important determinant of ability to race effectively at any level. This is the system used when doing extended (>5 minute) climbs, time trials, and long breakaways. The more power one can produce at threshold, the "higher" all the other intensity levels shift as a result, since threshold power is the anchor point.

Interval lengths for Threshold can be from 5-60 minutes, again depending on the purpose of the interval and the ride in general. One way to think of threshold is as the most power you can continuously make for an hour. As such, it makes sense that a workout focusing specifically on building threshold power should include at least 30 minutes of work at this level, but probably no more than 60. Interval lengths when focusing on training threshold power ought to be in the 15-30 minute range.

Shorter intervals can be used for *opening up* workouts, or as part of an intense warmup, but in general are not as effective at increasing threshold power as the longer blocks. The first 3-5 minutes of any interval in this zone are spent simply getting all metabolic systems up to speed. That's perfect as a warmup, or as part of an opening ride, but less than ideal if the purpose is to get 30-60 minutes of real training in this zone. A danger when performing shorter intervals without a powermeter, or without accurately knowing threshold power, is that the rider may be working at too high an intensity – and thus inducing fatigue associated with training in VO2 Max rather than threshold. A typical HR response while doing a steady interval at threshold power may take 3-10 minutes to rise to the bottom of the zone. All the factors that affect HR need to be taken into consideration when performing intervals in this zone in order to avoid starting too hard.

Longer intervals (15 – 30 minutes) ensure proper pacing in that if a rider starts too hard, it becomes painfully obvious after just a few intervals. Recovery between intervals generally ought to be enough to so as to not be out of breath, and certainly to handle any logistical concerns (drinking, turning around on the road, etc), but because these are still sub-threshold intervals there really is no minimal recovery duration. Some riders find they prefer to limit recovery between threshold intervals, as restarting after more than a few minutes break is often more challenging – especially on cold days.

Expected physiological benefits from training in this zone include increased mitochondrial density, increased plasma volume, improvement in VO2 Max, and increased sustainable power.

L5/Zone 5/VO2 Max

VO2max is the maximum rate at which a person's body can process oxygen. The rate of oxygen usage is measured in L/min, but is typically given as a ratio to bodyweight, in ml/min/kg. Typically a trained rider can maintain their maximum aerobic power for only 5-8 minutes. As a result, training interval length in this zone is 3-6 minutes, with 20-40 minutes of work ideal for a workout designed to improve VO2 Max.

The power zone for these efforts is 106 – 120% of threshold power, HR is less useful for efforts this short due to the issues around HR lag time. In a controlled lab situation, one would expect to see HR well over threshold HR at the end of a 5-minute VO2 Max interval, but HR is not an effective pacing tool for efforts of this length and below.

Although these efforts are designed to correlate with and improve VO2 Max, there is a significant anaerobic contribution to any effort that is by definition supra-threshold (above threshold). Due to the anaerobic contribution, intervals in VO2 Max and especially Submax require more recovery time (post workout) than intervals in lower intensity zones. As the maximum rate at which oxygen can be used, VO2 Max is the ultimate limiter of one's aerobic power production. One may think of it as the "ceiling" that caps a rider's potential to produce aerobic power. The reason why training at and below threshold is generally focused on much more than VO2 Max training is the high "cost" of these efforts.

From a coaching perspective, there's a lot more "bang for your buck" in using a high percentage of workouts that build aerobic capacity from a sub-threshold perspective, and are easier to recover from. Typically workouts that include VO2 Max or Submax are used sparingly, and only to elicit a final peak in riders preparing for specific events.

L6/Zone 6/Anaerobic Capacity (AWC)/Submax:

The interval length for this zone is 30 seconds to 2 minutes, generally with 2 to 5 minutes (complete) recovery. Never take a recovery period shorter than the interval period in this zone.

While the heart rate in this zone should be at or above lactate threshold, the delayed reaction of the heart to catch up to this effort makes going by heart rate somewhat useless, as with intervals in VO2 Max. The idea here is that the effort should be maximal for the duration specified. Essentially, you should begin the effort as if you were doing a sprint, and then attempt to hold the effort for the remainder of the interval. The intention here is to improve anaerobic work capacity (AWC), and lactate tolerance.

Measuring AWC is a difficult task that typically requires lab apparatus, although there are a few ways of estimating it using selected efforts and a powermeter. The idea in the Submax zone is to use up as much anaerobic energy as possible in as short a time as possible, thus training the body to create a bigger reserve of anaerobic energy for future efforts. The difficulty in picking interval duration is that 30 seconds almost surely does not exhaust AWC, while going out to 2 minutes does do this, but also becomes somewhat aerobic as anaerobic power supply is exhausted.

As with training in VO2 Max, only a very small amount of Submax is tolerable in a regular training program, and because the body responds very quickly to this type of training, it can be used very sparingly.

L7/Zone 7/ Sprints/CP Efforts:

The duration recommendations for this zone are 8-15 seconds in most programs, though recovery recommendations vary from 1 to 5 minutes. The intention with efforts in this zone is to increase the body’s neuromuscular power, and not lactate tolerance training. As a result one must be sure not to completely empty the body's store of creatine phosphate (CP) and turn the effort into one which uses a different fuel source (Submax), and to completely recover between efforts in order to ensure that CP stores are replenished. This happens quickly, but not so quickly to be foolproof. So, the interval can be viewed as one minute long: 8-15 seconds of maximal effort, and the remaining minute as recovery. Then the minimum rest required before the next interval is one minute. Thus, the tightest a sprint workout should ever be is an 8-15 second jump every second minute, but can be looser depending on time and recovery ability.

If the interval itself does not exceed 15 seconds, the effort will be primarily alactic; that is, minimal lactate will be produced, because glycogen is not a fuel source. If CP stores are not completely replenished before the next effort is made, CP cannot be used as a fuel source; the body turns to glycolysis and lactic acid is produced, creating an interval more appropriate for lactate tolerance. Thus the importance of full recovery between sprints.

Different cadences and sprinting styles should be emphasized based on the needs, strengths, and weaknesses of the rider. While sprints are maximal power efforts, they can easily become maximal speed-of-movement efforts by using a small gear and spinning upwards of 160 rpm. Conversely, they can also become maximal force efforts by using a very big gear (from a low starting speed) and moving at less than 60 rpm.

The number of sprints per workout and frequency of sprint workouts varies widely, again based on the needs of the rider. A rider focused on ultra-endurance events or individual time trials may only do a few sprint workouts per macro-cycle, while a track rider or criterium specialist may have weeks that include two sprint-focused workouts, with upwards of 20 sprints per workout. In cases like this with a relatively high number of efforts, there is also the potential to increase the body's CP stores as a result of training.

While improving neuromuscular power, speed of movement, strength, and increasing CP stores are all potential benefits of sprint training, sprint training also teaches riders valuable bike handling skills, and provides confidence when exerting maximal power in events. As such, even non-competitive riders will typically be prescribed training plans that include sprint training, albeit less extensively than some.