Optimal Training Intensity: Making Sense of Assessment Methods

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Optimal training is strongly influenced by the appropriate intensity prescribed for the desired training effect. Most endurance athletes (novice or pro) and coaches are familiar with the threshold concept that describes a cross-over from predominant aerobic (fat) metabolism to an increased contribution from anaerobic (carbohydrate) metabolism.[1] Most research agrees that the metabolic threshold is a strong predictor of endurance performance whereas VO2max or maximal heart rate are poor predictors of performance.[2,3] Therefore, most training zones are based around the parameters (heart rate, EMG, perceived exertion, blood lactate, power output) associated with the optimal training intensity of the metabolic threshold defined as ventilatory threshold (VT) or lactate threshold (LT).

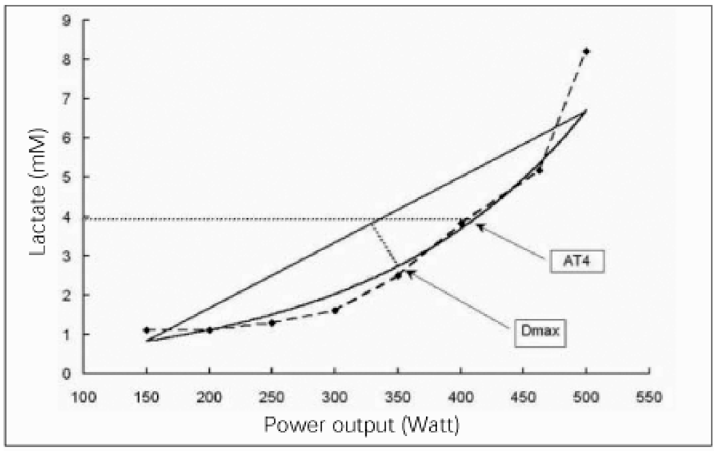

Fig. 1 *– Representation of AT4 and Dmax techniques to determine lactate threshold*   Source: Baptista et al. (2005)[4]

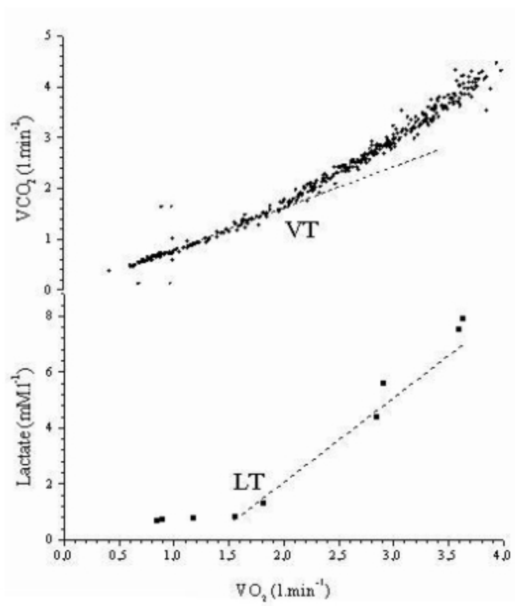

Fig. 2: A comparison between the ventilatory threshold (VT) and lactate threshold (LT). The threshold concept is described as a functional use of maximal aerobic capacity (VO2max). The onset of VT and LT may be dependent of the assessment protocol, diurnal patterns, or other physiological variables. Source: Sekir et al. (2002)[5]

The purpose of this article is to shed light on the pros and cons of various methods used to determine threshold-based training intensities beginning with the most simplistic heart rate formulas and ending with more sophisticated assessment protocols.

Karvonen Method

The most simplistic formula to establish training zones is called the Karvonen Method (1957)[6]. This method is determined from an age predicted maximum heart rate (MHR) and a resting heart rate (RHR) value to determine heart rate reserve (HRR). The percentage of MHR that desired for training is entered into the formula for the target heart rate, which is typically a range of 65-85% for threshold based training.

MHR = 220 – Age (years)

HRR = MHR – RHR

Target Heart Rate = HRR x desired %MHR + RHR

The Karvonen formula does not account for individual differences in metabolic fitness. It is effective for general health improvements and basic fitness, but it fails to yield significant improvements in performance simply because of the inability to assess sub-maximal changes in metabolic fitness and substrate oxidation (i.e. use of fats and carbohydrates). The assumption that RHR will proportionally decrease as fitness increases has not been examined in well-trained athletes. However, this limitation does not neglect the importance of monitoring RHR as a potential indicator of overtraining[7].

Maximal Aerobic Power and Heart Rate Deflection Method

The Maximal Aerobic Power (MAP) test has been used to determine the power output associated with short distance time trial performance.[8] MAP is often used to determine the heart rate deflection point (HRDP) and estimate a lactate or functional threshold heart rate (LTHR or FTHR) or FT power output. The strength of the heart rate deflection point to represent a metabolic threshold is controversial.[9-13] Much of the controversy revolves around the interpretation of physiological correlate of the HRDP, i.e. what does it exactly represent. The reliability and validity of the HRDP is protocol dependent and greatly influenced by the incremental increases in workload and stage duration.[14,15]

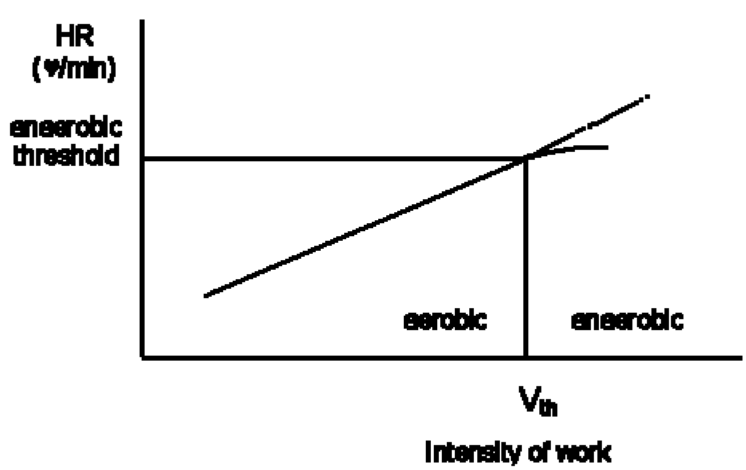

Fig. 3: The heart rate deflection point observed with an increase in work intensity.

MAP protocols are most often performed on treadmills, ergometers (Lode, Velotron, SRM) or Computrainers. The power output associated with the HRDP appears to be unreliable in the ability to predict the power output associated with functional threshold in cyclists. The HRDP may be a reliable method to assess heart rate changes related to fitness and to establish heart rate based intensities. Even though the HRDP may reflect a conceptual physiological threshold point, it fails to specify changes in metabolic fitness.

Field Tests

Field tests are commonly used to estimate the functional power output, velocity, or heart rate associated with the metabolic threshold or the maximal lactate steady state (MLSS), which is the exercise intensity that can be sustained from 20-90 minutes.[16-22] An athlete can record the average functional threshold heart rate (FTHR), velocity, or power output (FTP) over a time duration and formulate this into a variety of training zones by using coefficients or percentage-based formulas. The reliability of field testing is significantly influenced by pacing strategy, but it can be argued that improvements in pacing strategy also lead to improvements in performance.

The greatest drawback to field testing is that does not indicate changes in metabolic efficiency, which is highly correlated to the trained state of an endurance athlete.[23] The repeatability of field test performance is also related to recovery capacity, another variable related to metabolic fitness. Field testing may be more beneficial when assessing multiple time durations (5 seconds, 1 minute, 5 minutes, 20 minutes) to assess the maximal work capacity of specific energy systems rather than time trialing performance alone. The changes in work capacity may be a better indication of training progression and performance than a single field test measurement.

Laboratory Tests

In the past two decades, laboratory testing has expanded beyond the academic and medical institutions and into the commercial setting where more people have access to more sensitive assessment measures. Unfortunately this expansion has also decreased the quality control of the methods employed along with the technicians who administer and interpret the assessments. Whether it's measuring VO2max, VT, blood lactate, 3-D motion capture or electromyography, strong consideration needs to be given to the background of the technician to use proper methodologies and interpretations of the data. These issues aside, laboratory testing continues to provides the greatest measurement of numerous variables related changes in the trained status and metabolic fitness of an athlete.

As previously mentioned, trained status is highly related to type I muscle fibers (slow twitch or MyHC-I) metabolic efficiency and an increased reliance on lipids as a primary source of fuel at submaximal exercise intensities. The most sensitive measure of this improvement can be determined from the maximal fat oxidation capacity (FATMAX), which is the exercise intensity that elicits the highest amount of fat use as a fuel. [24] The higher the FATMAX, the greater the chronic training load or aerobic fitness level of the athlete, which also answers the question of sufficient endurance training "base". FATMAX is more quantitative and sensitive than blood lactate to determine the endurance fitness level of an athlete. FATMAX is greatly influenced by the functional capacity of the mitochondria that is predominant in MyHC-I fibers. It is perhaps more valuable for athletes who are attempting to lose weight and searching for training strategies to maximize fat loss during exercise. Training at 100% of FATMAX has been shown to significantly increase rates of fat use during exercise. FATMAX can only be determined via indirect calorimetry.

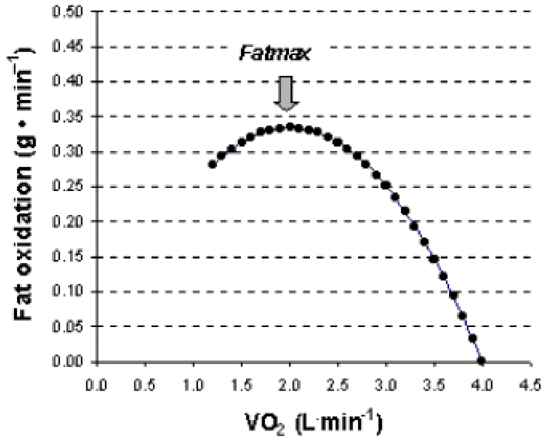

Fig. 4: FATMAX indicates the maximal fat oxidation associated with increases in exercise intensity. Source: Jeukendrup & Achten (2001)[25]

Of the laboratory tests, VO2max is probably the least applicable of all tests that assessment metabolic fitness for prescribing training zones. VO2max is valuable to determine the exercise capacity and genetic potential of an athlete. Caution should be taken to use VT variables (heart rate and power output) derived from a VO2max protocol for daily training prescription. To accurately assess VO2max, a protocol should be 8-15 minutes in duration.[26,27] The stage duration required to assess a quasi-steady-state of substrate metabolism is typical 3-8 minutes.[28] Optimal metabolic fitness for endurance athletes is determined by the increased ability to oxidize fat, reduce blood lactate, and decrease oxygen consumption at sub-threshold workloads in addition to achieving the highest functional use of VO2max.

Ventilatory and lactate threshold are often used to determine the metabolic threshold and are perhaps the best indication of the trained status of an athlete. The research is mixed on which of the two are more representative of the intensity associated with a 40-K time trial. However, most cyclists and triathletes are concerned about improving their metabolic fitness rather than targeting the 40K individual time trial or one-hour endurance test.

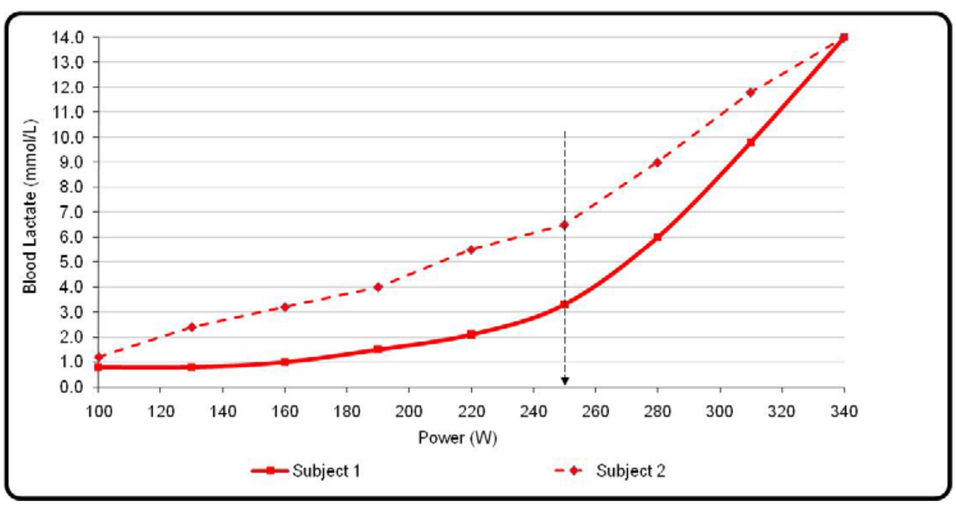

Fig. 5: The lactate threshold can be very similar between two athletes despite differences in sub-threshold metabolic fitness. In most cases, the Subject 1 will be able to repeat performances at lactate threshold (250W) more consistently than Subject 2.

The drawback of laboratory testing is that it is not in the natural environment of the athlete and discrepancies can be observed between indoor and outdoor variables above threshold. Much of the variation is related to the duration of exercise, hydration status, muscle and liver glycogen status, thermodynamics, and circulating levels of catecholamines. For example, the physiological response to a FTP of 250W after two hours of riding is very different than the physiological response to 250W after 20 minutes of riding. However, sub-threshold metabolic fitness (substrate oxidation) does influence a cyclist's time to fatigue, and therefore physiological response, for any given power output with increased exercise duration. This explains why professional cyclists can produce large power outputs after five hours of riding or several days of racing. Laboratory testing must be taken for what it is and not as the final determinant of performance, an obvious reason being that most competitive endurance events are dynamic and not steady state. Even time trial and triathlon courses have undulations that require an athlete to vary the pacing strategy. Power output has received a lot of attention in the past ten years as a unit of measure for universal comparison, but the power output generated by the athlete remains dependent of the metabolic response. A retrospective analysis of competition power meter or heart rate data can be useful for the intensity-specific training in preparation of upcoming events.

When using laboratory assessments, training zones should not default to a percentage-based system (i.e. % of FTP, LT, VT, or AT). Rather, training intensities should be prescribed based on the changes in metabolic response to increasing workloads or durations. In some cases, percentage-based system is adequate for training prescription. The best application of the results will be based on the limitations revealed in the assessment along with objectives that have been determined through a carefully planned needs assessment.

Conclusion

Although heart rate intensities derived from age, max values, and resting heart rates are commonly used to for general fitness prescriptions, they are not sensitive enough to elicit improvements in endurance performance for trained athletes. MAP protocols along with the heart rate deflection point may indicate changes in overall fitness, but the end result leaves the interpretation wide open as to the limitations in metabolic fitness and the future direction of training for the athlete. Field testing has a strong advantage because it places the athlete in the natural environment, but it also does not indicate changes in metabolic fitness unless it involves the use of laboratory instrumentation (lactate meters or metabolic carts). Field testing can be enhanced by assessing the power output or velocity associated with more than one time duration that is representative of a physiological energy system. Laboratory testing is the best indicator of metabolic fitness, although it is limited by indoor parameters used to estimate the outdoor conditions. A combination of laboratory and field assessments is the most effective method to determine the effectiveness of a training regime and to prescribe future training. The optimal training intensity and training zones should not be determined by a single variable, but rather the intensities associated with shifts in the individual metabolic response and metabolic demands of competition.

About the Author, Corey Hart, MS

Corey combines over ten years of international racing experience with evidence-based scientific research to improve the performance for athletes of abilities. After racing for five years in France and serving one year as the head coach at the Cycling Center in Belgium, he returned to the US to finish his Master's degree and reinvigorated the performance testing program at Colorado State University's Human Performance and Clinical Research Laboratory. He has coached national champions in the elite and master's categories in cycling. Corey has tested and provided training guidance for athletes from all over the world ranging from amateur athletes to world champions in triathlon, cycling, and hockey. Corey was a sports science consultant specializing in power data analysis for the performance enhancement team that guided the US women's cycling team to the 2004 Olympic Games. He continues to work with members of the US cycling team in addition to many professional and amateur endurance athletes. Corey is actively involved in designing field and lab testing protocols for USA Cycling development and talent identification camps. He has published research articles in the International Journal of Sports Medicine and in Medicine and Science in Sports and Exercise, published education articles in the USA Cycling Coaching Association's Performance Conditioning Cycling Journal, and provided author contributions to Outside Magazine, PezCyclingNews.com and in the book Triathlon Training Basics (by Gale Bernhardt). Corey is also a sports science consultant for the Baylor Cross Country and Track and Field team. Beyond the 15+ years of competitive, coaching and laboratory experience, Corey has also successfully directed men's and women's teams to victories and podium finishes in domestic and international competitions. Corey is currently the lab director at Physio Performance Lab and G-Fit Studio in Boise Idaho.

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