CRITICAL VELOCITY: A PACE BETWEEN

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With the rise of the Internet Age has come a rise in the number of readily accessible "oracles" of distance training knowledge. Many of these online personalities pass themselves off as pillars of wisdom in the running community on the message boards of such popular websites as Letsrun.com and Run-Insight.com. With all of their grandstanding and carelessly constructed late-night revelations, however, these false prophets mingle with some very well-educated, and sometimes, famous individuals (the likes of Dr. Jack Daniels, Renato Canova, and Brad Hudson) discussing everything from nutrition to mileage to interval training and threshold training. And thankfully, some of these interludes diverge from the juvenile jabs and blind-leading-the-blind blather, and turn the heads of even the most knowledgeable runners, coaches, and exercise scientists.

One such topic was able to span across several message boards and spawned many great responses, demanding that we, as students of the sport, take a second look. The topic of this discussion, and more specifically of this article, pertained to something called "critical velocity." This term, which sounds very imposing and forceful, is just as transparent and seemingly without definition as some of our other profound training terms in distance running (i.e. lactate threshold, anaerobic threshold, etc.) Just as these other terms have been given multiple names with just as many numerical values, so too has critical velocity in the scholarly literature of the physiological community. It has been referred to as critical speed, critical power, and critical velocity, with paces ranging from $vVO_{2\ MAX}$ down to that which would be comparable to MLSS (maximal lactate steady state, or a blood lactate level of approximately 4 mmol). With such a convoluted list of differing terms and paces, how then do you reconcile the initial question: What is critical velocity? And once that issue is resolved, then you must address the next quandary: How will training at my critical velocity improve my performance? In the end, by training at critical velocity, you can improve your aerobic profiles by:

1. Bringing about greater fractional utilization of $VO_{2\ MAX}$ in order to race faster at a lower percentage of $VO_{2\ MAX}$ for a given distance.
2. Improving extensibility – an athlete's capacity for running farther at a faster pace.
3. Performing LT – improving sessions with less volume at a greater intensity in order to keep legs fresher and stimulate an athlete's $VO_{2\ MAX}$.

WHERE DOES THE TERM CV COME FROM?

There are no secrets in distance running—no new revelations and no magic bullets. Somewhere, some other coach has already done it. Somewhere, some exercise physiologist has already written about it. Knowing this, however, has not stopped coaches from exploring better ways to train their athletes year to year. Knowing this does not stop us from picking through our copies of *Running with Lydiard*, *Road to the Top*, or *Daniels' Running Formula* to find that one piece of information that we may have glanced over without giving it the attention it was due.

It is this second look between the pages of established training theory, and this deeper understanding of the small spaces between breaths, heart beats, and strides that we find something called critical velocity—a concept that is not as new as it is overlooked in the common practice of distance running.

Critical velocity was initially noted in the research literature of the 1960's as being the highest intensity of exercise you could exert indefinitely without fatigue. As years have passed and more research has been done, this original definition has been amended several times over. The overwhelming conclusion has been that critical velocity is highly correlated with 10K race pace, and that this velocity is significantly correlated with running performances ranging from the 800 meters on up to the marathon. It has also been noted that once you begin exercising at a pace faster than your critical velocity, you will reach $VO_{2\ MAX}$ over time. By training at the critical velocity, then, you can maintain a high percentage of your $VO_{2\ MAX}$ and a lactate steady state for the duration of the individual reps of your workout, thereby initiating both $VO_{2\ MAX}$ and lactate threshold improvements. This allows us to view critical velocity, then, as a measure of aerobic endurance. It is only logical, then, to draw the conclusion that by training at the critical velocity, you can improve your aerobic profile, and in turn, improve your race day performances.

However, all of this information is derived from trials in a lab, and not from practical application on the track. These studies do not tell us how to determine what the critical velocity is for each individual runner, nor do they tell us specifics on what we can accomplish by training at this velocity. This is where the science of coaching meets the art of coaching.

WHAT DOES CV MEAN IN TRAINING TERMS?

"Critical velocity is a pace that you can sustain for some 45 minutes," says exercise scientist and private coach Tom Schwartz. "For some people, then, this would be either just faster than or just slower than 10K race pace." Schwartz, who has coached many successful high school, collegiate, and post-collegiate athletes, has used this definition of critical velocity to guide him in his endeavors. "By training an athlete at their critical velocity, a coach can improve the runner's lactate threshold while simultaneously stimulating their $VO_{2\ MAX}$."

At UC Davis, we are dealing with athletes who obviously run 10,000 meters faster than 45 minutes, so we set our critical velocity training pace between 10K pace and lactate threshold pace (see Table 1). Although we do have tables of our own here at UC Davis, it is suggested that coaches use the USATF Coaches Education Program's % of $VO_{2\ MAX}$ method of determining training paces. The breakdown is as follows:

USATF Coaches Education Program's % of $VO_{2\ MAX}$ Pace Chart

800 meters	120-136% of $VO_{2\ MAX}$
1500 meters	110-112% of $VO_{2\ MAX}$
3000 meter	100-102% of $VO_{2\ MAX}$
5000 meters	97-100% of $VO_{2\ MAX}$
10000 meters	92% of $VO_{2\ MAX}$
Lactate Threshold	88% of $VO_{2\ MAX}$
Half-Marathon	85% of $VO_{2\ MAX}$
Marathon	82% of $VO_{2\ MAX}$

Critical velocity, then, would be within the range of 89-91% of $VO_{2\ MAX}$, but where? Schwartz says that this is up to the individual coach. "If you are looking for greater gains in $VO_{2\ MAX}$, set your critical velocity closer to 10K pace. If it is lactate threshold improvement that is more essential to you, place the pace close to lactate threshold velocity."

We know from the training literature of Dr. Joe Vigil and Dr. Jack Daniels that $VO_{2\ MAX}$ improvements can be made by exercising at 90-100% of $VO_{2\ MAX}$. We also know that the most significant training component for an athlete in an endurance event is the lactate threshold session, in which an athlete is looking to train to delay OBLA (onset of blood lactate accumulation) in order to perform at a higher intensity for longer before the body is crippled by H+ ions – ions that accompany acidosis, which leads to a reduction in speed over time. If you were able to train, then, at a pace that stimulates $VO_{2\ MAX}$ and raises the lactate threshold, Schwartz says that this would improve your ability to run farther faster, and at a lower energetic cost.

"It is about extensibility," says Schwartz. "If an athlete can extend their speed over a greater distance at the same effort as before—that is the goal in training distance runners. That is what training at the critical velocity is about." Therefore, by adding critical velocity sessions to your training program, you will be able to improve your fractional utilization of $VO_{2\ MAX}$ —something Dr. Vigil cited in his article from an earlier issue of Peak Running (July/Aug 2005) as being vital to the success of Deena Kastor in Athens. By improving your fractional utilization, you can perform at a faster pace for a longer distance at a lower percentage of $VO_{2\ MAX}$ velocity, thereby bringing about improvement across all distances relating to submaximal velocities. Using critical velocity sessions will allow you to improve your buffering capacity during extended periods of exercise—i.e. go longer and faster at a higher blood lactate concentration level.

WHY CV AND NOT LT OR 10K?

The question that would be asked next then would be, “Why not just train at lactate threshold or 10K pace?”

There are two reasons for choosing to train at a velocity between these two conventional paces. The first aspect to consider is that when you train at 10K pace (or 92% of $VO_{2\ MAX}$), the volume of this work must be reduced because of the respective intensity. Top collegians may do up to 10,000 meters of work at this pace, but they will need substantial amounts of recovery from the wear and tear this can have on the body. The potential for injury or soreness from a session of this magnitude is certainly increased. However, by training at critical velocity, an athlete can still reap the benefits of $VO_{2\ MAX}$ stimulation by running at the reduced intensity of 90% $VO_{2\ MAX}$ and increase the volume of work. This lends itself to the idea of extensibility—covering more distance at a smaller cost of energy—by allowing the coach to boost an athlete’s $VO_{2\ MAX}$ while concurrently raising their lactate threshold. The second reason for training at this pace is that when you train at the lactate threshold, you are not stimulating your $VO_{2\ MAX}$, making the training session very one-dimensional. By turning the intensity up a notch (by a mere 2-3%), you can bring the $VO_{2\ MAX}$ stimulus into the picture while continuing to bolster the lactate threshold (without crossing dangerously into a state of distress). Several studies have shown that by training at a pace just above lactate threshold velocity, you can, in fact, raise your lactate thresholds more effectively than by training below this pace. So the argument then becomes, why not train faster? This also adheres to the goal of extensibility, wherein you can now train at a pace that will allow you to not only run for longer distances with less fatigue, but also to do so at a faster pace at a smaller percentage of $VO_{2\ MAX}$. In turn, this athlete will also be able to call upon a greater percentage of their $VO_{2\ MAX}$ during longer races, allowing them to carry a greater velocity longer—i.e. improved fractional utilization of $VO_{2\ MAX}$.

DETERMINING YOUR CV PACE

To determine your critical velocity, the easiest method is to begin with a recent race or time trial performance. It is best to perform a race or trial effort that is at or near their chosen race distance, as this will be more accurate in determining subsequent training paces. At UC Davis, we have performed time trials in the early season of cross country and track & field that allow us to construct individual training parameters for each of our athletes. These trials have been over specific distances (5K & 8K before cross country, 1600m, 2400m & 3000m before outdoor track) or over specific periods of time (6-minute run and 10-minute run). Based on these results, we are able to devise training paces, including critical velocity, for each of our athletes. The type of trial is selected based on the types of athletes we are testing. For example, an early season test of our 5K & 10K runners may be the 3000m run, as this will give us an accurate current race pace, allowing us to extrapolate through percentages of that performance what their various training paces will be at other distances. We set critical velocity at a pace that is roughly 2-3% faster than lactate threshold, or at 90-91% of $VO_{2\ MAX}$. We have had great success with this intensity level, and we have found that this allows us to perform a quality session without sacrificing volume (i.e. extensibility) or risking injury.

WHAT MAKES UP A CV TRAINING SESSION?

A critical velocity training session should generally be a collection of repetitions that can range in length from 800-3000 meters, although I prefer 1000, 1600, and 2000 meter segments. I have found that the rest between segments should be roughly 1:00 of rest for every 1000 meters run. As for total volume per session, Schwartz suggests 6-8% of weekly total mileage can be comprised of critical velocity training. At UC Davis, our critical velocity sessions add up to 4-6 miles at pace, which is in-step with Schwartz’s suggested totals and are at a level we find beneficial for our athletes. During the sessions, we remind our athletes that this not a gut-wrenching workout, but rather a demonstration of a more natural feeling of speed. The sessions should be run on similar surfaces to that which you are racing on, and should be performed under similar conditions to ensure accuracy. We want these sessions to be confidence-inspiring, not energy-depleting. Therefore, *do not perform a cut down from the critical velocity pace*. This is *very* important because once you dip below critical velocity and begin running at 10K pace or faster, you will be running more of a VO_2 -type workout, rather than one that focuses on extensibility and lactate threshold improvement. A critical velocity workout should leave you feeling exhilarated, not trashed. Here is an example of one of our common CV sessions:

1. Warm-up 10-20 minutes; dynamic warm-up drills; light strides
2. 3-4 x 2000 meters @ CV pace w/ 2:00 rest

3. 5-10 minute light jog
4. 4-6 x 200 meters @ 1500m effort w/ 200 jog recovery
5. Cool down 10-20 minutes; stretch; ice

Runner A

Current 10K Time: 30:36 (4:53.7 per 1600m)

Critical Velocity: 4:56.0-5:00.0 per 1600m

CV Workout: 4 x 2000 meters @ 6:10-6:15 w/ 2:00 rest

6 x 200 meters @ 1500m effort w/ 200 jog recovery

Runner B

Current 10K Time: 35:00

Critical Velocity: 5:37-5:41 per 1600m

CV Workout: 4 x 2000 meters @ 7:00-7:05

6 x 200 @ 1500m effort w/ 200 jog recovery

Runner C

Current 10K Time: 40:00

Critical Velocity: 6:26-6:30 per 1600m

CV Workout: 4 x 2000 meters @ 8:03-8:08

6 x 200 @ 1500m effort w/ 200 jog recovery

The 200 meter repeats at the end of the session are important; we are calling upon you to finish the workout at a faster pace, much like the final laps of the 5,000 or 10,000 meter races. We are conditioning you to run faster in a fatigued state.

WHERE DOES CV FIT INTO THE ANNUAL TRAINING CYLCLE?

Critical velocity is a useful training pace at any point of your season, whether it be in cross country or outdoor track. At UC Davis, we have used critical velocity very effectively during the latter part of cross country, the early weeks of outdoor track, and again during the peaking phase of the outdoor track season. We position the sessions during these periods for several reasons. During the last few weeks of the summer build-up and into the first month of the cross country season, we implement a mixture of short, medium, and long tempo runs, varying the length of the efforts from 4-12 miles (depending upon each athlete's mileage goals and the pace being implemented). The paces range from 82-88% of $VO_{2\ MAX}$, and we cycle through them during the course of 3-4 week mesocycles. This allows us to safely raise the runners' lactate thresholds without inhibiting their aerobic development by mistakenly dipping into the faster paced work too soon. Thereby, we jump-start the improvement of their fractional utilization of $VO_{2\ MAX}$. Once we have done this for 6-8 weeks, we are ready to start implementing the critical velocity training in conjunction with a second hard workout of the week, which will focus on improvement of velocity at $VO_{2\ MAX}$ and race pace efforts.

Because college runners have generally trained at a high level for several years, gains in $VO_{2\ MAX}$ may be minimal, depending upon an athlete's training age and mileage. However, with critical velocity, you can improve your capacity to run at a greater velocity at all percentages of your $VO_{2\ MAX}$. This means improvement in all aerobically dominant events, which we have learned range in distance from the 800 meters to the marathon. Therefore, in the latter part of a cross country season, training at critical velocity while working concurrently on improving velocity at $VO_{2\ MAX}$ is especially important. As you improve your maximum velocity at the point of your maximum oxygen uptake, you will also be enhancing your ability to run faster at a lesser aerobic cost.

Once you have accomplished this improved state of fractional utilization at the end of your racing season, you do not want your progress to slip to pre-racing levels, so you must stimulate the system early in the build-up for outdoor track. Also, because of critical velocity's correlation to 10,000 meter pace, it serves as a fine way to build the athlete into the outdoor racing season and for the bigger upcoming meets. Then, during the months of March and April, we shift our focus to training at and below race pace, with lactate threshold improvement taking a secondary role. Because of the increase in intensity—both in racing and training—we find it wise to move away from the more aggressive LT-improvement method of critical velocity in order to improve the quality of our race pace sessions. However, as the end of the season comes around, with the volume of work decreasing a bit, we do not want to allow our aerobic system to suffer from lack of stimulus. Therefore, we bring critical velocity back into play in order to "get more bang for your buck"—by reducing volume, you are set for the most important meets while still massaging your $VO_{2\ MAX}$. This will boost your lactate threshold, and maintain the integrity of your overall aerobic profile. Below is a training sample week that includes a critical velocity session:

A Sample Week of Training Including a CV Session

SUN – Long run @ 65-70% of $VO_{2\ MAX}$ (20-25% of weekly mileage)

M – Recovery run w/ grass strides to follow (mileage as needed)

T – Repetitions @ 3K-5K pace (3000-8000 meters total volume) w/ short reps @ 800m-1500m effort to follow

W – Medium run @ 75-80% of $VO_{2\ MAX}$ (15% of weekly mileage)

TH – Recovery run w/ grass strides to follow (mileage as needed)

F – Repetitions @ CV pace (4000-10000 meters total volume) w/ short reps @ 1500m effort to follow

SAT – Recovery run (mileage as needed)

TO CV OR NOT TO CV

One day, I was discussing the different approaches coaches use to train athletes in the same events. My coaching friend and I were amused by the idea that people are always looking for "The Way" to train—some mythical plan or session or pace that will solve all of their distance running problems—when in fact, there are so many ways we can accomplish similar goals. Finally, my friend turned to me and said, "You know, there are a lot of roads that lead to Sears." Critical velocity is just one of those roads. If you decide to take that road—well, that is entirely up to you.

References

Billat LV (2001) Interval Training for Performance: A Scientific and Empirical Practice Part I. Sports Med 31 (1):13-31.

Billat LV (2001) Interval Training for Performance: A Scientific and Empirical Practice Part II. Sports Med 31 (2):75-90.

Bosquet L, Leger L, Legros P (2002) Methods to Determine Aerobic Endurance. Sports Med 32 (11):675-700.

Daniels J (2005) Daniels' Running Formula. Human Kinetics, Champaign, Illinois.

Dekerle J, Baron B, Dupont L, Vanvelcenaher J, Pelayo P (2003) Maximal lactate steady state, respiratory compensation threshold and critical power. Eur J Appl Physiol 89:281-288.

Florence S, Weir JP (1997) Relationship of critical velocity to marathon performance. Eur J Appl Physiol 75: 274-278.

Franch J, Madsen K, Djurhuus MS, Pedersen PK (1998) Improved running economy following intensified training correlates with reduced ventilatory demands. Med Sci Sports Exerc 30 (8): 1250-1256.

Henritze J, Weltman A, Schurrer RL, Barlow K (1985) Effects of training at and above the lactate threshold on the lactate threshold and maximal oxygen uptake. Eur J Appl Physiol 54:84-88.

Hill DW, Ferguson CS (1999) A physiological description of critical velocity. Eur J Appl Physiol 79:290-293.

Keith SP, Jacobs I, McLellan TM (1992) Adaptations to training at the individual anaerobic threshold. Eur J Appl Physiol 65:316-323.

McLellan TM, Cheung KSY (1992) A comparative evaluation of the individual anaerobic threshold and the critical power. Med Sci Sports Exerc 25: 877-882.

Monod H, Scherrer J (1965) The work capacity of a synergic muscle group. Ergonomics 8: 329-338.

Saunders PU, Pyne DB, Telford RD, Hawley JA (2004) Factors Affecting Running Economy in Trained Distance Runners. Sports Med 34 (7): 465-485.

Schwartz, Thomas M. Personal Interview. 15 August 2005.

Smith CGM, Jones AM (2001) The relationship between critical velocity, maximal lactate steady-state velocity, and lactate turnpoint velocity in runners. Eur J Appl Physiol 85: 19-26.

Vigil, JI (1995) Road to the Top. Creative Designs, Albuquerque, New Mexico.

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