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VO2 MAX-EFFORT LIFT

BY CHRISTIAN LARSON

Once considered the gold standard of fitness, VO_2 max is now just one aspect of athletic performance.

CrossFit has blurred the line between conditioning and strength work. For example, gymnastics and barbells can be combined in intervals that dramatically affect the aerobic system.

CrossFit athletes rarely face long, single-modality tests. In most cases, traditional "cardio" activities are combined with other elements, creating interval work. In the 2014 Reebok CrossFit Games, a 3,000-m row was followed by 300 double-unders and a 3-mile run.

"By analyzing the amount of oxygen you consume, the (VO_2 max) test determines how efficiently your body extracts and uses oxygen from the air. This makes it the gold standard of fitness markers, as well as a strong indicator of your overall health."

That statement appeared in the April 21 Menshealth.com article "5 Health Tests That Could Save Your Life" (7).

Do you think it's correct? Incorrect? Partially correct?

As CrossFit athletes, we're interested in a broad and inclusive fitness, high levels of general physical preparedness (GPP) and increased work capacity. CrossFit training is often characterized by intensity, and many CrossFit athletes aren't especially fond of long, steady-state workouts that require lower intensity due to their duration. That's OK, because we can achieve aerobic adaptations through the interval work that has always been a large part of CrossFit programming.

"Properly structured, anaerobic activity can be used to develop a very high level of aerobic fitness without the muscle wasting consistent with high volumes of aerobic exercise!!" CrossFit Founder and CEO Greg Glassman wrote in the CrossFit Journal article "What Is Fitness?" "The method by which we use anaerobic efforts to develop aerobic conditioning is 'interval training'" (4).

The more we understand about the mechanics of aerobic adaptation, the better the foundation for solid programming, so let's take a quick look at these adaptations through the lens of the Fick equation, named for German physiologist Adolf Eugen Fick.

What the Fick?

The Fick equation reads as follows: $VO_2 = Q \times (a - vO_2)$.

- VO_2 is the amount of oxygen utilized by our bodies, measured in liters per minute.
- Q is cardiac output—heart rate (HR) x stroke volume (SV). HR is measured in beats per minute, and SV is defined as the amount of blood ejected from the heart per beat (ml/beat).
- $a - vO_2$ is the difference in arterial and venous oxygen content, measured in ml of oxygen per 100 ml of blood. This is a measure of oxygen extraction at the tissue (skeletal muscle for our purposes).

The question: "How does training affect these variables and allow us to improve our VO_2 max?"

We know that the two determinants of VO_2 max are genetics and training, with genetics being the major contributor (about 60-70 percent genetics versus about 30-40 percent training) (2).

Alterations in Fick-Equation Variables With Endurance Training

Rest:

$\leftrightarrow VO_2 = \leftrightarrow Q \times \leftrightarrow (a - vO_2)$

$\leftrightarrow Q = \downarrow HR \times \uparrow SV$

Max Exercise:

$\uparrow VO_2 = \uparrow Q \times \uparrow (a - vO_2)$

$\uparrow Q = \leftrightarrow HR \times \uparrow SV$

Let's look at cardiac output first, referencing the above equations.

With aerobic training, we see a couple of changes in the determinants of Q (cardiac output) at rest. Resting Q remains the same, but SV increases, allowing for a lower HR (training bradycardia).

As we examine the max-exercise equation for cardiac output, we see a couple of changes post training as well. Q has increased, max heart rate is unchanged (but may decrease), and SV has increased. At this point we can eliminate HR as a causal factor in increasing VO_2 max. SV increases with aerobic training—but how?

One of the first adaptations to aerobic training is increased blood volume due to increases in plasma and red blood cells, leading to an improved capacity to transport oxygen. The increased blood volume also increases the stretch on the left ventricle, leading to increased filling. These two adaptations lead to a larger amount of blood ejected per beat—a larger stroke volume.

The third variable in the Fick equation—a - vO_2—also increases with training. In untrained individuals, the difference at rest is about 5 ml of O_2 per 100 ml of blood, and it increases to about 15 ml of O_2 per 100 ml of blood at max exercise. As you can see, oxygen extraction at the muscle increases with increasing exercise intensity. With aerobic training, this difference can increase to about 18 ml of O_2 per 100 ml of blood, meaning the body becomes better at offloading oxygen at the muscle.

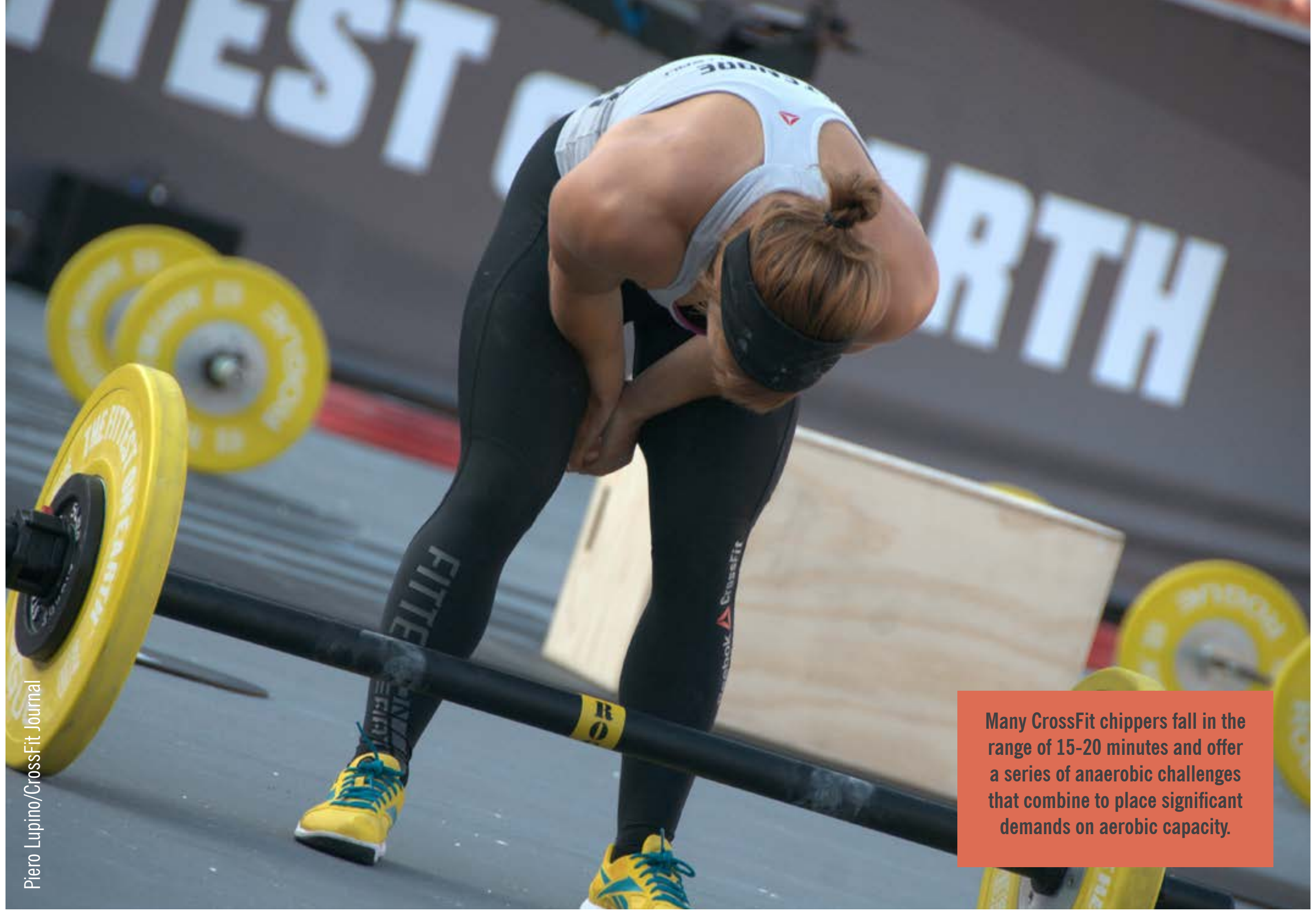
By looking at the Fick equation, we see part of how we adapt aerobically: primarily via increases in stroke volume (due to increased blood volume), and to a lesser extent via increases in the difference between arterial and venous oxygen content.

In application, this gives us an understanding of the rationale behind the CrossFit exercise prescription. For workouts lasting longer than two minutes that require an elevated heart rate for the duration, we will likely see some aerobic adaptation even if the workouts include lifting or gymnastics and are far from the "steady-state conditioning" common in running, cycling or other endurance sports.

> "Strive to blur distinctions between 'cardio' and strength training. Nature has no regard for this distinction or any other."
> —Greg Glassman

"Strive to blur distinctions between 'cardio' and strength training. Nature has no regard for this distinction or any other," Glassman wrote in "What Is Fitness?"(4).

In the CrossFit Level 2 Trainer Course, it is suggested that we keep the majority of our workouts shorter than 15 minutes because this time domain allows for the manipulation of intensity and movements to provide broad adaptation in strength, power and aerobic endurance. All three are important for the development of GPP.



Piero Lupino/CrossFit Journal

Many CrossFit chippers fall in the range of 15-20 minutes and offer a series of anaerobic challenges that combine to place significant demands on aerobic capacity.

Thomas Campitelli/CrossFit Journal

CrossFit's best athletes have impressive endurance and stamina in addition to amazing strength, flexibility, power, speed, coordination, agility, balance and accuracy.

The Gold Standard?

This leads us back to the Men's Health quote:

1. "By analyzing the amount of oxygen you consume, the test determines how efficiently your body extracts and uses oxygen from the air."

For the purposes of this article, the description is adequate.

2. "This makes it the gold standard of fitness markers, as well as a strong indicator of your overall health."

Men's Health is obviously referring to aerobic capacity—not GPP—as "fitness," and if VO_2 max were indeed the gold standard, we wouldn't need to run distance races anymore. We would simply have athletes test their VO_2 maxes and declare a winner.

CrossFit Games champion Rich Froning Jr. posted a VO_2 max of 73.9 ml/kg/min to Instagram early in 2015 (3), and while the number is definitely impressive when compared to normative data, it's unlikely Froning's success can be attributed to VO_2 max alone. But would this number make him a better endurance athlete than those with lower VO_2 max numbers?

Olympic marathon champions Peter Snell (72.3 ml/kg/min) and Frank Shorter (71.3 ml/kg/min) recorded VO_2 maxes lower than Froning's (6), but Froning would not have been competitive in a marathon with these athletes.

Although a relatively high VO_2 max is important to be successful in endurance activities, other markers correlate more closely to overall fitness: lactate thresholds and critical power (1,5,9).

Lactate threshold is the point at which lactate begins to accumulate in the blood during exercise, and critical power is determined by using test results to graph power output against time and determine the point at which power decreases level off as time increases. These two variables are also more "trainable" than VO_2 max, and the more one can increase these variables relative to VO_2 max, the longer higher work rates can be maintained.

For example, if two people have the same relative VO_2 max and compete in an endurance-based event, the one with the higher lactate threshold and/or greater critical power will likely win (all else being equal). This could also hold true for someone with a lower relative VO_2 max and higher lactate threshold and/or greater critical power.

Four-time CrossFit Games champ Rich Froning Jr. boasts an impressive VO_2 max of 73.9 ml/kg/min, but it's more likely his success can be attributed to his lactate threshold and critical power.

Furthermore, it should be obvious to CrossFit athletes that cardiovascular/respiratory endurance is but one of CrossFit's 10 fitness domains. It's rather useless in CrossFit if an athlete hasn't the strength to lift a barbell or the flexibility that will allow him or her to achieve optimal positioning in movements.

What about VO_2 max as a strong indicator of "overall health"? The literature seems to back that up if we're talking about cardiovascular health, but once a certain VO_2 max level is reached, continued improvements don't decrease the risk of chronic cardiovascular disease (for normative VO_2 max data, see 10). In conditions such as heart failure, VO_2 max dips into the very bad range, and patients may hit their max VO_2 simply trying to walk across the room. Obviously, this lack of exercise tolerance becomes a major concern (8,11,12).

While VO_2 max might have been considered a gold standard of endurance at some point, we have demonstrated that it is but one of several important variables, and its status as the gold standard is not backed up by data. VO_2 max should be regarded as one of many variables involved in fitness, defined as increased work capacity across broad time and modal domains.

Now go do Murph and increase your stroke volume! ■

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About the Author

Christian Larson lives in Manhattan, Kansas, with his wife, Lindsay, and daughters Avery and Delaney. He received a B.S. and M.S. in kinesiology with an emphasis in physiology from Kansas State University. He is an instructor and advisor in the Kinesiology Department at Kansas State, teaching undergraduate courses in biomechanics and exercise science. Christian is also the coordinator of K-State CrossFit, which is housed within the Kinesiology Department. He is a CF-L3 trainer and a member of CrossFit Inc.'s Seminar Staff as part of the CrossFit Kids team, and he sits on the Certified CrossFit Trainer Board. Christian is the fourth best athlete in his family. Christian gives special thanks to Dr. Ryan Broxterman for editing and content assistance.