

## **Lactate and Lactic Acid - Good or Bad?**

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One of the most interesting challenges that coaches and exercise physiologists face is to explain exercise physiology in an easy-to-understand way. A common goal is to provide athletes with useful and applicable information to optimize their exercise behavior. Unfortunately, the oversimplification of concepts can lead to misunderstanding. The common understanding of lactate has suffered this unfortunate fate.

The belief that lactate or “lactic acid” is the cause of fatigue in working muscle was a convenient explanation for complex processes. Since the appearance of lactate increases as exercise intensity increases, and as exercise intensity increases, fatigue increases, some assumed that lactate caused fatigue. If we didn't understand heart rate as well as we do, we might assume the same correlation between heart rate and fatigue. Heart rate and fatigue both increase as exercise intensity increases, but we know that heart rate does not *cause* fatigue. The same is true of lactate.

To really understand lactate requires a fair understanding of biochemistry and physiology. However, even many of the current physiology textbooks are outdated with regards to the information they provide about lactate. There is quite a bit of interesting new (and not so new) research that has shed much light on our understanding of lactate metabolism. Let's examine a few popular misconceptions.

*The accumulation of lactate causes fatigue in muscles.*

- Lactate does not cause fatigue, and on the contrary is a useful and efficient fuel source<sup>2</sup>.

*Lactic acid can be measured in the blood using a lactate analyzer.*

- Lactic acid does not exist in the blood. As soon as it is produced, the substance thought to be lactic acid disassociates into lactate and hydrogen (More on lactate and hydrogen below). A lactate analyzer measures the concentration of lactate (a useful fuel) in the blood.

*Lactate clearance and lactate tolerance refer to how the body deals with fatigue.*

- Since lactate does not cause fatigue, its clearance from the blood depends on the body's ability to use it as fuel. The body not only tolerates lactate, but it sometimes prefers lactate over glucose as an energy source<sup>6</sup>.

*Measuring lactate is a reliable means of measuring performance.*

- This point is heavily debated. Although lactate production increases progressively as exercise intensity increases, the ability to use lactate as fuel varies from person to person and varies with one's trained level, fed and rested state<sup>5</sup>. The ability to

use lactate as fuel will also vary the amount that will appear in the blood at maximum sustainable workloads<sup>4</sup>. This evidence suggests that a fixed lactate concentration may not be a reliable predictor of performance.

*Measuring lactate values reflects the accumulation of hydrogen, which is the fatigue-causing substance at non-sustainable workloads.*

- Lactate and hydrogen both result from anaerobic metabolism. While the accumulation of hydrogen may contribute to fatigue, it is not reflected as a one-to-one ratio with the appearance of lactate in the blood. More importantly, there is new evidence that mechanisms other than hydrogen accumulation are significant sources of muscular fatigue at non-sustainable workloads<sup>8, 9</sup>.

## **Energy pathways**

Understanding lactate requires a basic understanding of exercise metabolism. The body uses metabolic pathways to provide fuel to working muscles. Each of these pathways converts a particular type of fuel into ATP. ATP is a high-energy molecule that enables the actual contraction of muscle fibers.

The three metabolic pathways are the aerobic (with oxygen), anaerobic (without oxygen) and creatine phosphate (CP-ATP) systems. The most immediate energy pathway is CP-ATP. This is a very short-lived (few seconds) and extremely fast method of providing energy.

The aerobic pathway is the most complicated in terms of the steps involved, but yields the largest amount of ATP and allows the use of many types of fuels such as fats, proteins, glucose and lactate (yes, lactate). The conversion of these fuels into ATP requires various steps within the muscle cell. Oxygen and fuel need to be delivered into the mitochondria (mini-organ “aerobic furnaces” within cells) during this process to produce ATP aerobically. While the aerobic pathway is the slowest ATP producer of the three pathways, it is also the most efficient.

The anaerobic pathway, on the other hand, is very fast at providing ATP to working muscles since it does not require as many steps. Furthermore, its primary fuel source glycogen (stored glucose) is locally available, stored in and around the muscle itself, making its conversion to ATP a quicker process. The anaerobic production of ATP is also called glycolysis (breakdown of glucose).

The process of glycolysis (anaerobic production of ATP) results in the formation of lactate and hydrogen. These two products, while produced from the same reaction, disassociate and have different fates in the body. If lactate and hydrogen were to remain a single unit, then it would be lactic acid. It is unlikely however that you would find any lactic acid in the blood. Lactate can remain in the cell for energy or leaves the cell and travels to active and inactive muscles to be used as a fuel<sup>1</sup>. The ability to use lactate as

fuel, particularly within the muscle itself, varies with the trained characteristics of aerobic muscle, specifically via endurance training<sup>5</sup>.

Other fates of lactate include transport to the brain or cardiac muscle for fuel or to the liver to be converted to glucose. During exercise, the body works to maintain the availability of glucose for the brain. The making of glucose (gluconeogenesis) is an important function of the liver while exercising, and lactate is the most important precursor for the process of gluconeogenesis<sup>3, 7</sup>.

While the hydrogen ( $H^+$ ) resulting from glycolysis can lower pH, increasing acidity, much of the  $H^+$  is buffered, converted to  $CO_2$  and simply exhaled. If the accumulation is severe, there is evidence that it may interfere with muscular contractions. However, glycolysis is not the only contributor to an increase in acidity and hydrogen is not the only contributor to fatigue. Fatigue appears to result from a combination of an accumulation of hydrogen and other metabolites such as inorganic phosphate<sup>9</sup>, as well as the inability of muscle to keep up with the rates and force of contraction through the progressive loss of potassium from inside the muscle cell<sup>8</sup>.

## Summary

For the sake of understanding, athletes have been taught that lactate is the root of all evil. However, while easy to relate to athletes, this paradigm has hindered what has really been known about lactate for the last 5-20 years. Lactate is *not*: 1) present as lactic acid in any appreciable amount in the blood, 2) the direct cause of fatigue at higher workloads, or 3) directly predictable of acidity. Lactate *is*: 1) a valuable energy source within the working muscle, non-working muscle, and heart, 2) quantitatively the most important contributor to the making of glucose in the liver, and 3) subject to training-induced improvements in its use as a fuel. Just as many 'old school' athletes had to adjust to the idea that rest is good for training, the idea that lactate is 'good' continues to fight a similar resistance.

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