The Equine Heart: Part 1
What Makes the Horse Such an Amazing Athlete?

Without a doubt, one of the most awe-inspiring things about our equine companions is their remarkable athleticism. Their sheer power, grace, and refinement of movement have captivated the imagination of people throughout history. But beyond the sinew and muscle and bone of these intricate machines is a power plant unequalled in any other creature: the equine heart.

In some ways, the job of the heart is really quite simple: it is mainly just a pump. Blood must be moved from one area of the body to another. What makes the equine heart so remarkable is its adaptability and efficiency in doing this job under different conditions.

The Role of Blood
Blood must circulate throughout the body for many reasons. The most obvious is the delivery of oxygen ($O_2$) from the lungs to the tissues, and carbon dioxide ($CO_2$) back from the tissues to the lungs. Blood also transports nutrients and by-products to and from the intestines and other internal organs.

Additionally, blood works in the same way that radiator fluid works in a car, carrying heat away from the power source to an area of cooling. Muscles (like a car engine) convert fuel into movement. The car engine and muscle both produce waste heat which must be removed to prevent overheating of the system. The main radiator in the horse is the skin, followed by the lungs.

A Smart Pump
The equine heart has many ways of adapting to differing demands. Cardiac output is the measure of blood pumped per minute. Cardiac output is calculated by multiplying the heart rate by the amount of blood pumped with each beat, termed stroke volume. Stroke volume is close to one quart of blood per heartbeat. So, a horse with a heart rate of 40 beats per minute pumps 40 quarts of blood (10 gallons) every minute.

The average resting heart rate in an athletic horse is typically between 32-40 beats per minute, while maximum heart rate at a full gallop can exceed 240 beats per minute. In humans, the typical athlete has a resting rate in the 50-60 beats per minute range, with a maximum heart rate of about 220. Besides increasing the rate, the heart muscle increases the amount of contraction (increasing the stroke volume) when requirements increase, pumping out the maximum volume possible.

Obviously, a lower cardiac output is required at rest than at maximum exercise levels. The heart limits the amount of energy expended in three main ways. First, the heart rate is decreased. Second, the amount of contraction of the heart muscle is decreased, pumping out only part of the volume of blood in the heart, (decreasing stroke volume). Third, the heart can skip a beat allowing the heart to rest. This change in heart rhythm is called 2$^{nd}$ degree AV block, which is normal in horses, and is occasionally seen in human athletes.

Racing Arabians, Thoroughbreds, and Quarter Horses
A critical difference exists between horses of different disciplines in terms of cardiac requirements. Compare the Arabian, Thoroughbred and Quarter Horse to Olympic marathon, middle distance runners and sprinters. From one group to the next, we see a shift from extreme endurance to prolonged strength to raw power.
The difference in these groups comes from the difference in muscle type. The ‘slow twitch’ or Type I muscle fiber produces less power, but can continue to work for extended periods.

The Arabian horse has primarily Type I fibers, which can utilize fat and sugars in the presence of oxygen for sustained moderately fast-paced aerobic exercise. Below about 140 beats per minute, most endurance horses can deliver all the oxygen their bodies require. Above this heart rate, termed the lactate threshold, the horse’s muscle must start exercising anaerobically. Anaerobic exercise uses faster-produced and shorter-lived fuel from sugars, and produces lactate. Excessive lactate production can lead to fatigue and even muscle damage. An endurance horse exercising below its individual lactate threshold will recover rapidly and be able to sustain for the longer distances because it is exercising aerobically.

The Thoroughbred racehorse has a mixture of Type I and Type IIa or ‘intermediate twitch’ fibers. Type IIa fibers produce more power than Type I fibers, and rely on sugars for fuel. The larger more efficient hearts of Thoroughbreds allow for the type IIa fibers to use oxygen at a high rate for a longer period of time. The more efficient the heart, the more aerobic use of sugars can be maintained, pushing off fatigue.

The Quarter Horse has mostly type IIb or ‘fast twitch’ fibers. Type IIb fibers produce the most power, but rely on unsustainable anaerobic exercise. A sprinting Quarter Horse can accelerate more rapidly than any other horse, with speeds clocked at around 50 miles per hour. But this maximum rate can not be sustained beyond a half mile. Because the racing Quarter Horse relies on anaerobic exercise during this sprint, heart size is not as large as in Thoroughbreds.

The Sedentary Steer, the Cross-Country Skier, and the Racehorse

In an interesting study, the horse was compared to the steer to show differences in ability to sustain exercise. Among the striking differences were vast differences in lung capacity and heart size. Comparing animals of the same weight, researchers found the lung and heart volumes to be twice as large in the horse.

Researchers use the term VO$_2$max to measure the oxygen carrying potential in different individuals on a per weight basis. An elite cross-country skier had the highest measured VO$_2$max in a human of about 96mL/kg/min, while measurements almost twice as high may be reached in the Thoroughbred racehorse. In cattle, VO$_2$max is more in the 30-40mL/kg/min range.
Conditioning

As in humans, the ability of the heart to function efficiently relies on exercise. Increasing the strength of heart muscle improves the stroke volume, which allows the heart rate to decrease at rest.

Heart Size

Of all equine athletes, Thoroughbred racehorses have the largest and most efficient hearts. Part of this is genetic, and part is from their rigorous training. Typical heart weights are in the 10-12 pound range. Phar Lap, the famous New Zealand-born racehorse, had a heart that weighed 14 pounds. The heart of Secretariat was believed to be even larger. (The autopsy performed on Secretariat was incomplete, so some have suggested that some of the enlargement could have been from common age-related heart problems.)

The size of the Thoroughbred heart has been watched closely, and is believed to be influenced most by the X chromosome. The ‘X-factor’ is a horse-picking system based on this, which contends that heart size can be predicted genetically, and that larger heart size means better performance. While heart size is an important factor in performance, other factors are obviously critical as well, so relying on the ‘X-factor’ alone is dubious.

Size also can increase with disease. Hearts which become overly enlarged are actually less efficient, whether in humans or horses. It is common for older horses to have leaky valves, which can eventually lead to congestive heart failure, where the heart enlarges well beyond that of the fittest racehorse. (This topic will be discussed further in The Equine Heart Part 2: Common Cardiac Disease.)

Matt Durham, DVM grew up in Reno, Nevada. During the summers growing up, Dr. Durham worked in the Sierra Nevadas as a backcountry guide at McGee Creek and Mammoth Lakes Pack Outfits, where he met his wife, Tiffany. He attended Cal Poly, San Luis Obispo, and obtained a degree in Animal Science. After graduating from veterinary school at UC Davis, he performed a one year internship at Alamo Pintado Equine Medical Center in Los Olivos, California. After four years in practice, he performed a one year fellowship in large animal cardiology and ultrasound at the University of Pennsylvania’s New Bolton Center. Dr. Durham has been at Steinbeck Country Equine Clinic since 2001.