The Equine Heart

How it works & what can go wrong

By Todd C. Holbrook, DVM

The horse's heart and blood vessel (cardiovascular) system is one of the key components required for optimal athletic performance. The modern-day horse has evolved over thousands of years with selective pressures aimed at improving athletic performance. This has resulted in an animal with a large heart which has high blood pumping capacity. In this article I will review some of the basic functions of the heart, the cardiovascular response to training and exercise, as well as review some causes of poor performance related to heart function.

The heart as a pump -- why is this important?

The horse's heart, like ours, has four chambers with associated valves that open and close as the heart muscle relaxes and contracts to insure blood flows in the right direction. Specialized cells within the heart conduct electrical activity that coordinates the muscles of the heart to contract in an appropriate manner to optimize blood pumping. The right and left atria are smaller volume chambers at the top of the heart that receive blood returned from either the lungs (left atrium) or the body (right atrium).

When the atria contract, each delivers blood to the larger volume ventricle that lies beneath. The right side of the heart receives un-oxygenated blood from the body and pumps it to the lungs to allow the red blood cells to uptake oxygen. Oxygenated blood returns to the left side of the heart, and the left ventricle pumps it out the aorta to the rest of the body.

Simply stated, the larger the heart is, the more volume of blood it can pump. Thus, heart size is a major determining factor of stroke volume (SV) or the volume of blood pumped per heart beat. Stroke volume in a horse at rest is around 1000 ml, and increases to around 1700 ml at maximal exercise. The cardiac output (CO), or volume of blood pumped per minute, is equal to the heart rate (HR) multiplied by the stroke volume.

With exercise onset, the horse's heart rate increases from a resting rate of 30 to 40 beats per minute to around 110 beats per minute. Stroke volume increases also, due to increased volumes of blood returned to the heart. The heart muscle responds to this increased volume and pressure with stronger contractions.

Thus with the initial demands of exercise, cardiac output rapidly increases. This increase is required to supply working muscles with oxygenated blood. The maximal oxygen uptake or VO2 max is also known as aerobic capacity. Among animals of comparable size, the horse is superior in its ability to consume oxygen (>200mlO2/min/kg).

It is generally accepted that the ability of the horse's muscle mass to consume oxygen far exceeds the ability of the heart and lungs to provide oxygenated blood. Thus conditions that result in improved cardiac output positively impact performance, whereas conditions resulting in reduced cardiac output can directly negatively impact performance.

Do athletes with bigger hearts perform better?

As explained above, the larger the heart, the higher the cardiac output. The impact of heart size on performance is supported by relative heart sizes in famous human and equine athletes. One multiple Olympic champion distance runner had a heart mass that was almost three times larger than predicted for his body size. Triple Crown winner Secretariat's heart was estimated to be 22 pounds, nearly 10 pounds heavier than the heart of an unexceptional stallion. The impact of cardiac size on endurance performance in the horse is currently unknown; however, a number of famous endurance horses anecdotally had large hearts.

In racing Thoroughbreds, maximal oxygen consumption is an excellent determinant of performance, and heart size is related to both VO2 max and racing performance. Whereas elite Thoroughbred racehorses perform near VO2 max at top speeds, endurance horses typically compete at 30% to 55% VO2 max.

What's different about the cardiovascular requirements of endurance exercise?

Exercising muscles produce excessive heat during work that must be balanced with efficient body cooling. Increases in cardiac output are required not only for working muscle, but also to supply blood flow to the skin to allow for optimal sweating and heat dissipation.

In the endurance horse, the thermoregulatory system is of utmost importance. Comparatively, much more cardiac output is required for thermoregulation with endurance work than with short distance racing. During endurance exercise, fluid loss from sweating can reduce circulating blood volume. The resulting competition for cardiac output between working muscles and skin can become critical. Because the central cardiovascular needs take precedence, skin blood flow is reduced to maintain circulating blood volume and heat stress often results.

The maximal heart rate in the horse varies from just over 200 to around 240 beats per minute. During racing, Thoroughbreds typically achieve heart rates that are close to maximum, while endurance racing horses typically maintain a lower working heart rate for long periods (120 to 160 beats per minute). However, with sprints at race finishes, elite endurance horses also likely achieve heart rates approaching maximum.

How does the cardiovascular system respond to training?

As horses become more fit with training, a number of adaptations occur in the cardiovascular system. In both humans and dogs, endurance training causes a reduction in resting heart rate. Although I am not aware of a study that addresses this question in endurance horses, my impression is that resting heart rate also decreases with training in endurance horses. Most literature of cardiovascular exercise physiology addresses the Thoroughbred race horse, wherein there is not a reduction in resting heart rate with fitness.

Heart rate during submaximal exercise does decrease with training. In other words, the heart rate required to trot or canter at a set speed from point A to point B will be reduced as the horse becomes more fit. The heart rate monitor is a valuable tool when utilized to assess fitness in this manner.

Although there is a linear relationship between running speed and heart rate, maximal heart rate is not a good measure of athletic fitness. Furthermore, maximal heart rate is not increased with training. Speed or velocity at a specific submaximal heart rate is related to stroke volume, fitness and performance.

The reduced heart rate during submaximal exercise is due to a number of factors that are altered with training. Blood volume increases in horses due to training by about 10%. This increased blood volume is due to both increased plasma volume and red blood cell volume. These changes optimize oxygen-carrying capacity, and provide greater plasma volume for improved thermoregulation. The increased blood volume is one factor that leads to increased cardiac stroke volume secondary to training. Mathematically, because CO = HR x SV, the increased stroke volume induced by training provides the maintenance of cardiac output for submaximal exercise, while allowing a reduction of heart rate.

The heart itself remodels in humans and dogs as a result of endurance training. Recent studies in racehorses indicate remodeling also occurs in the horse in response to training. Heart mass and the left ventricular internal diameter increases with training. The size of the left ventricle has also recently been correlated with performance in both Standardbred and Thoroughbred racehorses. The impact of endurance training on cardiac remodeling in the horse, and the importance of heart size on endurance performance, have not been studied.

How is heart rate recovery affected by training and exercise?

As with improvement in fitness, the heart rate recovery time post-exercise is shortened. In other words, the horse's heart rate drops more rapidly toward normal after exercise as fitness improves. Checking the heart rate monitor at intervals after completing a defined distance is a valuable method to assess fitness during training. During competition the rider and veterinarian often utilize this information on the ride card to monitor the horse's condition. With dehydration, metabolic dysfunction, fatigue and even lameness, heart rate recovery is adversely affected. This is the basis of the cardiac recovery index (CRI).

How can heart problems cause poor performance?

Adequate cardiac output must be maintained to sustain muscular work; therefore, any condition that results in reduced cardiac output below that necessary for a given workload can reduce performance. In the horse, reduced cardiac output can result from arrhythmias (abnormal heart rhythm) that cause uncoordinated contraction of the heart.

Heart murmurs can also be associated with poor performance. If one or more of the heart valves does not close properly, this can disrupt normal blood flow in the heart and cause a heart murmur. Depending on the location, severity, and duration of the valve leakage, changes in cardiac function can result which may negatively impact athletic performance.

The most common arrhythmia that causes poor performance in horses is atrial fibrillation. During this condition, the electrical activity of the top chambers of the heart (atria) is uncoordinated. This results in reduced pumping of blood to the ventricles, as well as an irregular ventricular rhythm. The resulting reduced cardiac output can cause poor performance.

I have diagnosed paroxysmal atrial fibrillation that has developed during competition in a number of endurance horses. In this situation it may be related to electrolyte disturbances. Indeed in one recent case it was associated with inappropriate calcium supplementation during competition. Horses that develop atrial fibrillation during competition should receive veterinary attention. Evaluation will usually include assessment of the horse's serum electrolyte status and electrocardiogram recording. The condition may resolve over time with correction of the electrolyte abnormality. Because there can be other causes of atrial fibrillation, and this arrhythmia can indicate underlying heart disease, a thorough cardiac workup is recommended.

Other exercise-induced arrhythmias may also result in poor performance. The diagnosis of these problems often requires evaluation of the horse's heart rhythm during exercise on a treadmill.

Heart murmurs are quite common in horses, especially athletes. Rapid blood flow out the major vessels at the heart base during contraction of the heart commonly results in innocent flow murmurs that are not caused by valve leakage. These are normal murmurs caused by turbulent blood flow, and do not impact on the horse's performance. It can be difficult to determine the seriousness of a murmur by the stethoscope alone, and sometimes even suspected innocent flow murmurs should be confirmed with a more in-depth cardiac workup. Because specialty equipment and advanced veterinary training is often required for extensive cardiac workup, this often necessitates transport of the horse to a university teaching hospital or referral clinic.

Murmurs associated with the valves between the atria and the ventricles can result in poor performance, especially on the left side of the heart (mitral valve). Mitral valve insufficiency can result in heart enlargement, atrial fibrillation, and ventricular arrhythmias. A thorough cardiac examination including ultrasound of the heart (echocardiography) is warranted in any horse that has a significant heart murmur.

One of the more common murmurs I recognize in older endurance horses is called aortic insufficiency. In this disease, there is a progressive degeneration of the aortic valve, and as the valve function worsens it results in reduced performance. After the left ventricle contracts to pump oxygenated blood out the aorta, the insufficient valve allows blood to flow backwards into the left ventricle during the resting phase of the heart cycle. This results in a reduced effective cardiac output. This murmur is more common in horses over 15 years of age. I have heard a number of rather loud aortic insufficiency murmurs in older endurance horses that have competed for years with the condition at lower levels. Because it is a progressive disease, horses with aortic insufficiency should be monitored over time with echocardiography.

In this article I have briefly reviewed some basic concepts of how the horse's heart functions during exercise and how a few conditions can affect performance.

Todd C. Holbrook, DVM, Diplomate ACVIM, Assistant Professor of Equine Medicine at Oklahoma State University in Stillwater, Oklahoma