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Everything is energy. How to unleash the full potential of your horse? The horse is an exceptional athlete whose performance is underpinned by the dynamic interrelationships between respiratory, cardiovascular, musculoskeletal, neuroendocrine and energy systems that enable them to perform. For optimal performance, all of the physiological systems work together holistically to provide the fuel or energy to generate and maintain movement. This article will explore the role of energy in race horse performance and consider how we can adapt training programmes to facilitate optimal performance for the individual horse.


RGY

DR. JANE WILLIAMS IS AN ASSOCIATE PROFESSOR AND HEAD OF RESEARCH AT HARTPURY UNIVERSITY. SHE IS AN EXPERIENCED RESEARCHER, WITH A PASSION FOR ENHANCING EQUINE PERFORMANCE AND WELLBEING THROUGH INDUSTRY-INFORMED, REAL-WORLD RESEARCH THAT GENERATES CHANGE.

Jane qualified as a Veterinary Nurse then gained her Masters in Equine Science before completing her doctorate exploring the application of surface electromyography as a tool to assess muscle adaptation during training in racehorses and sport horses.

Her main areas of professional interest include scientific evaluation of equestrian performance, training and wellbeing, rider impacts on equitation, reliability assessment across equestrian science and veterinary physiotherapy, and human-animal interaction. Jane co-edited and authored 'Training for Equestrian Performance' with Dr. David Evans, to showcase how science and research can be applied practically to improve performance for horses and their riders, and has published over 100 research articles as well as regularly presenting at international equine conferences.

She is also Honorary President for the International Society of Equitation Science, which promotes the application of objective research and advanced practice, to improve the welfare of horses in their associations with humans. Jane is also a founding member of the Sport horse Welfare Foundation.

Exercise in the horse requires energy; this is provided at a cellular level to drive performance by adenosine triphosphate or ATP. However, as in all mammals including humans, the horse does not just have one method to generate the energy it needs for locomotion. It is important to remember that a combination of aerobic (where oxygen is utilised as the main fuel) and anaerobic (where energy comes from other sources: primarily fats and carbohydrate stores) are used during exercise. Four energy pathways are used to support performance through the production of adenosine triphosphate or ATP as shown in the table below.

Aerobic vs. anaerobic energy utilisation

The type of energy utilised will be related to the type, duration and intensity of exercise being undertaken as well as the fitness and the muscle fibre blueprint of the horse. When oxygen is being utilised as the key fuel to generate energy or ATP, the horse is exercising aerobically, and when energy production does not involve oxygen it is anaerobic. In reality both aerobic and anaerobic energy pathways will be recruited to support exercise from moderate to high intensity levels. Stamina in performance is associated with aerobic pathways while fast explosive 'power' activities such as sprinting over short distances and jumping are associated with anaerobic pathways. Therefore, while flat horses coming out of the starting stalls, National Hunt horses when jumping and horses starting to tire will utilise anaerobic energy predominately, the bulk of performance for the equine athlete should be fuelled by aerobic pathways to achieve their best.

ENERGY PATHWAYS IN THE HORSE

<table>
<tr><td>Aerobic phosphorylation of adenosine diphosphate (ADP) using carbohydrate or glycogen stores in muscle tissue to generate ATP</td><td rowspan="2">These two pathways are collectively known as oxidative phosphorylation (require Oxygen)</td></tr>
<tr><td>Aerobic phosphorylation of ADP using fatty acids or beta-oxidation to generate ATP</td></tr>
<tr><td>Anaerobic phosphorylation of ADP using high energy phosphate stores in skeletal muscle to generate ATP</td><td rowspan="2">Non-oxidative phosphorylation</td></tr>
<tr><td>Anaerobic phosphorylation of ADP using carbohydrates or glycogen muscle stores to generate ATP</td></tr>
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Summary of energy pathways and muscle fibre recruitment from low to high intensity exercise in the horse.

Generally aerobic energy pathways produce energy at a faster rate but at a lower efficiency than anaerobic pathways, which while efficient, uses fuel available more quickly and depletes sooner producing lactate as a by-product. The accumulation of lactate is associated with the onset of fatigue and generally lactate values over the threshold of 4 mmol/l in the blood is indicative of fatigue. Excessive accumulation of lactate within muscle contributes to intracellular acidosis and fatigue, and can contribute to exertional rhabdomyolysis or tying up, however the energy production needed for galloping cannot occur without lactate production. Training programmes of >6 months have been demonstrated to improve the horse's ability to remove lactate efficiently from the muscle cells, which can aid in reducing the negative effects of intracellular lactate accumulation on muscle acidosis and fatigue processes. In effect slowing the onset of fatigue and improving race performance. In reality horses are individual and lactate thresholds vary, with superior performers likely to possess more fast-twitch glycolytic fibres capable of generating glycolytic ATP at faster rates, able to tolerate larger increases in intracellular and blood lactate, and with muscle fibres capable of removing lactate from contracting muscle at high rates, giving them a performance advantage.

Race performance and considerations for training

In racing, a combination of aerobic and anaerobic energy recruitment is required to achieve optimal performance. Training programmes are designed to improve aerobic fitness, delaying the onset of the need to recruit the anaerobic pathways to support performance. A common method used across sport science for humans and horses, to assess an athlete's individual aerobic capacity is to measure the rate of maximal oxygen uptake or VO2max: the velocity or speed when maximal oxygen consumption is achieved. It is a common misconception that the volume of air taken in each breath is the limiting factor for aerobic performance, while air (oxygen) input into the respiratory system is can be a limiting factor to equine performance, it is the uptake of oxygen at tissue level in the muscles which is key to performance. Therefore, for optimal performance, the horse requires a functional respiratory system to take in oxygen and an efficient cardiovascular system to transport the oxygen to the cells in the muscles where it will be turned into aerobic fuel for locomotion i.e. we train to improve aerobic capacity and delay the onset of fatigue.

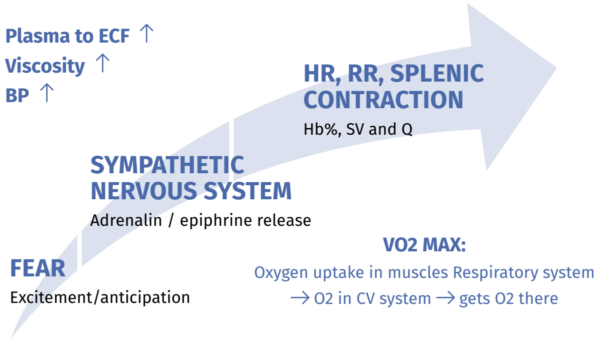
Assessing VO2max is difficult in the horse as it requires a maximal exercise test, for example running to fatigue on a treadmill, and while this is achievable, it is not something we would normally undertake unless investigating poor performance. However, luckily, research has demonstrated that VO2max has a positive linear association with heart rate up to approximately 200 beats per minute in the horse. This means we can utilise heart rate as a proxy measure for aerobic capacity and facilitates access to monitoring aerobic performance via heart rate monitoring systems. The anaerobic threshold, when the horse has to utilise anaerobic energy pathways as well as aerobic during exercise, is considered to be between 75 to 85% of maximum heart rate; in our studies using racehorses we will commonly use 80% as the average threshold value. Heart rate in the horse ranges from resting values of 25 - 40 bpm to approximately 220 - 250 beats per minute (bpm) during maximal exercise; age will also influence maximum heart rate. Vincent et al (2006) proposed a simple, user-friendly method to estimate the anaerobic threshold for a horse which is easy to utilise:

Anaerobic threshold HR value using 80% of VO2max:

(HR max using 240bpm as an average – age of horse = age adjusted HR max) x 0.80 = anaerobic threshold (bpm) e.g. for a 4 year old racehorse: (240-4 = 236) x 0.80 = anaerobic threshold of 189 bpm

Traditionally racehorse training has been based on subjective rating of horse performance, visibly assessing the horse or via the assessment of the rider. Regular use of heart rate monitoring combined with assessment of lactate are a positive addition to a training regime. Having access to heart rate data can through the use of HR monitoring ideally with integrated GPS to also record speed and distance, provides the trainer with additional information that can be used to determine the level of work a horse is undertaking and can help quantify fitness levels by providing objective data that can be recorded and monitored across time to enable the trainer to be fully informed about the level of exercise the horse is undertaking to inform their decision-making. For example, many trainers will utilise interval training within their programmes; the premise of this form of training is to undertake bouts of short duration, high intensity exercise to develop fitness but to be successfully implemented, the horse should recover before subsequent bouts. In an outdoor environment it is unlikely that a horse's heart rate will drop to resting levels as heart rate is also influenced by behaviour and the horse reacting to its environment. However, our work has found that often rider assessment of when a horse is recovered during interval training is not accurate and the horse's heart rate is still high. We advocate the use of HR monitoring in this situation and using baseline recovery to walking heart rate levels of ~70-90 bpm before starting subsequent exercise bouts to get the maximum benefit from interval training.

Another key tool for assessment of fitness in the horse is the integration of a standard exercise test (SET) into a training programme. A SET, is as the name suggests, a comparative piece of work that can be utilised at regular intervals, we would recom-



RESPONSE TO EXERCISE IN THE HORSE

mend every 3 or 4 weeks, to assess training progress. This can be a set distance at a consistent speed perhaps utilising the same gallops where heart rate and lactate can be monitored to assess progress; as aerobic fitness increases, HR and lactate should reduce for the same standard test.

Regular monitoring of heart rate and converting average heart rates to the percentage of HRmax a horse is working at across intervals or pieces of work can be a beneficial addition to the trainer's tool kit, helping assess performance potential by comparing workload to a known superior performance, to assess fitness, to be sure that the training plan is being executed and to prevent overtraining by providing data to show the level the horse is actually working at. Converting heart rates to % HRmax is easy to do: average HR / age-adjusted maximum HR x 100% and can be easy to plot and monitor across time. For example: A 4-year-old racehorse, with average HRs for an interval training session: bout 1: 190bpm, 2: 203bpm; 3: 226 bpm would be working at 81%, 86% and 96% of HRmax.

Recovery post exercise is also an important consideration; horses are amazing athletes and their heart rate will drop after exercise much quicker than humans, which is why we recommend using HR systems that monitor continuously. It is unrealistic to expect a racehorse's heart rate to return to resting levels during a warm down from exercise but ideally, we are aiming for recovery levels of between 50-70 bpm within 5-10 minutes of the cessation of exercise, with the caveat that the environmental conditions can influence this. Monitoring the reduction of heart rate at 2-minute intervals post exercise can be another useful tool to assess fitness and performance potential in the racehorse. Extended recoveries can indicate the workload level is incorrect for the level of fitness of the horse.

Muscle is also important!

Skeletal muscle can make up to 40% of a racehorse's bodyweight and provides the fundamental, mechanism for energy production to drive locomotion. Thoroughbreds as a breed have a genetic predisposition through selective breeding to possess increased quantities of Type IIB and Type X muscle fibres that support high intensity, shorter duration exercise compared to breeds such as the Arabian, which are utilised for more endurance, low intensity activities (increased Type I and Type IIA fibres). It is important to also recognise that muscle fibre profiles while determined by genetics, can be influenced by training regime and the introduction of canter and gallop exercise in a training regime will result in some Type I, slow twitch fibres transiting to Type IIAX fibres to support the increased exercise demands.

Energy stores in the muscle are vital for optimal performance. Muscle glycogen concentrations in horses at rest are approximately 100 mmol/kg of wet muscle, rising to 150 mmol/kg in trained horses, however these stores can be used up quickly with a single exercise session capable of depleting reserves by a third and a high intensity exercise session by up to 50%. Therefore, when planning training and racing schedules considerations should be given to the energy demands of repeated exercise and allowing sufficient recovery time for muscle energy reserves to replete (which can take between 48 and 72 hours) before the next bout of intense exercise or a race will occur.

Final thoughts

Racehorse success is measured in terms of performance at the races, however more than ever how the industry safeguards racehorse welfare is being scrutinised by non-racing stakeholders who question racing's social license to operate. Utilising evidence-informed training methods can reduce the risk of injury and have the potential to extend the careers of racehorses, be that in racing or their second careers when they leave the track, but also can support trainers to enable optimal performance from the racehorses in their care. Understanding how energy systems underpin performance and how we can increase and monitor aerobic athletic capacity as well as monitoring horses as individual athletes should help to achieve this.

ANAEROBIC <180BPM ← VS → **AEROBIC** >180BPM

EXERCISE LEVEL	LOW INTENSITY	MEDIUM INTENSITY	HIGH INTENSITY**
	Walk → Working trot	Extended/Collected trot → Working canter	Galloping and Jumping
FIBRE RECRUITMENT	Type I^{+++} → Type IIA^{+}	Type I^{+} → Type IIA^{+++} → Type IIAX^{++}	Type I^{+} → Type IIA^{+} → Type IIAX^{+++} → Type IIX^{+++}

THE ANAEROBIC / LACTATE THRESHOLD IS USUALLY ATTAINED AT 75 – 85% HR MAX
HR MAX FOR HORSE = 220 – 240 BPM, SO ANAEROBIC THRESHOLD IS **~ 178 – 204 BPM**

SUMMARY OF ENERGY PATHWAYS AND MUSCLE FIBRE RECRUITMENT FROM LOW TO HIGH INTENSITY EXERCISE IN THE HORSE.

* Vincent et al., 2006 | ** Or prolonged submaximal exercise)