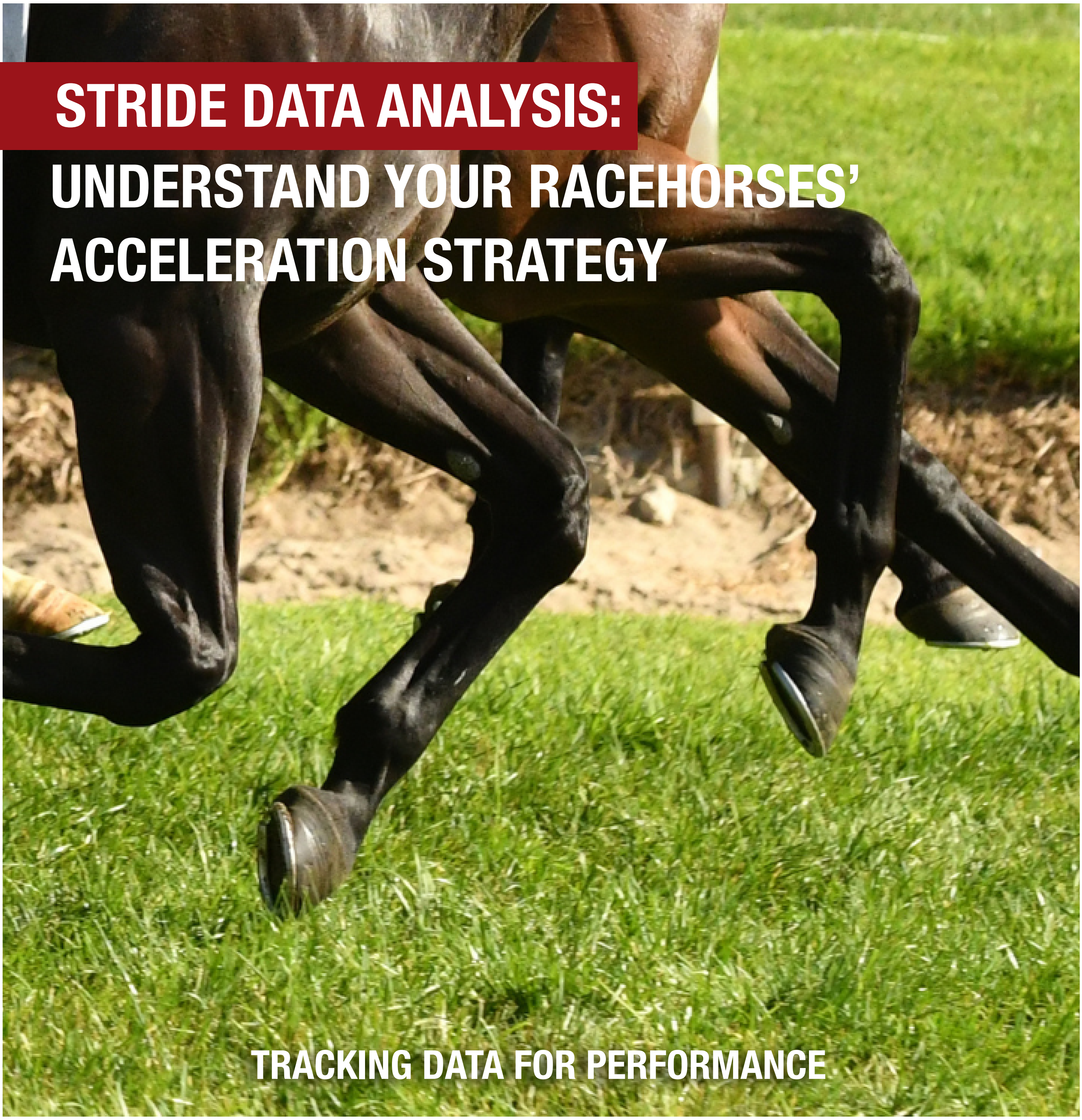
ARIONEO

HORSE DATA SCIENCE

STRIDE DATA ANALYSIS:
UNDERSTAND YOUR RACEHORSES' ACCELERATION STRATEGY



TRACKING DATA FOR PERFORMANCE

INTRODUCTION

THE RACEHORSE'S LOCOMOTION

Nowadays the racehorse is considered as a top athlete. Although his abilities rely on his physical, cardiac and respiratory capacities, these are not enough to define him as a good or bad athlete. Identifying his locomotor profile allows to analyze and characterize his locomotion.

How does the horse use his limbs to move? How can his speed and energy utilization be improved?

The analysis of the horse locomotion involves the observation of his movement as much as the interpretation of data such as: his speed, his stride length, and his stride frequency.

It provides valuable insights into his physical abilities, his fitness and his potential. Locomotion analysis can also reveal pain at an early stage. These characteristics can be assessed by an expert eye or by the rider's feelings but getting an objective and scientific measurement of these parameters allows for precise monitoring.

Speed = Stride length x Stride frequency

To objectivize the horse locomotion, one should look at the stride length and stride frequency pair. A study of these parameters makes it possible to:

DETECT INJURIES

How can the data collected by EQUIMETRE be used to detect locomotor pain? What situations require attention from trainers?

IDENTIFY THE LOCOMOTOR PROFILE

How does the horse change his locomotion according to the terrain? How to get the most out of a horse according to his locomotor profile? Are there any differences in locomotion depending on the distance of the race?

DETECT FUTUR PERFORMERS

What makes a good horse?
What are the reference points among the great champions?

In this white paper, we will first study the specificities of locomotion through the gait symmetry and regularity. In a race, depending on the track, the locomotion allows the horse to adapt his gait to the curve, the slope and the type of ground.

Based on these elements, we will see how to analyze speed aptitudes through the study of locomotion, then how to improve the locomotor strategy when preparing for a race.

Finally, monitoring the locomotion in the long run enables to detect pathologies and their warning signs.

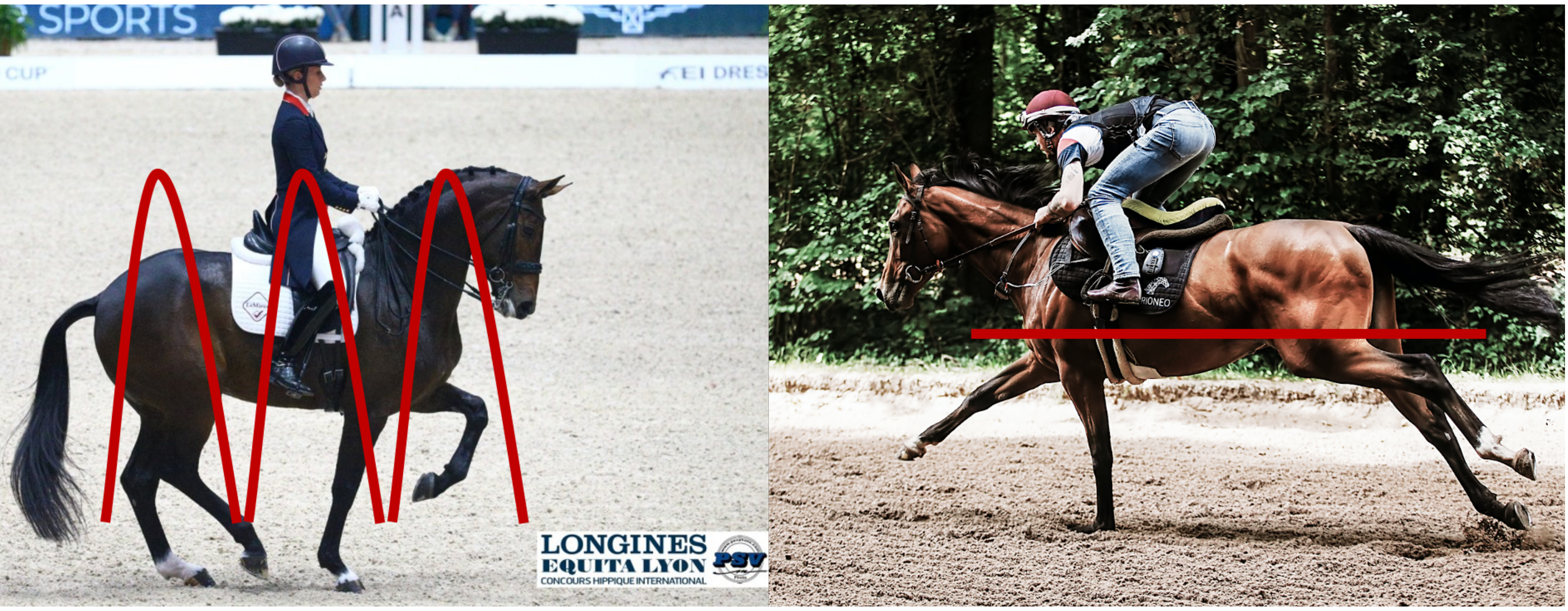
We aim to give the keys to collect, analyze and make the best out of locomotion data for performance optimization and health monitoring.

We will call **«Locomotor Profile»** the stride frequency and stride length pair of a horse at a given speed (60 km/h for thoroughbred).

Thinking that it is better to have a large stride length than a large stride frequency would be a mistake. The first is a witness of limb power, the second, when correlated with speed, shows the efficiency of the cardio-respiratory system and great acceleration abilities.

CHAPTER 1 | THE RACEHORSE'S SPECIFIC LOCOMOTION CHARACTERISTICS

The trot and gallop are two jumping gaits: for a brief moment none of the horse's limbs are in contact with the ground. This suspended time can be used to rise in height, e.g. dressage horses will try to increase this bounce whereas racehorses use all their energy to propel themselves forward. Any vertical movement can thus be seen as a loss of energy.



Movement of the center of gravity in a dressage horse and in a racehorse. The dressage horse has a center of gravity moving vertically: he jumps. The center of gravity of a racehorse is almost at a fixed altitude: his strides are low and wide.

1 SPECIFIC LOCOMOTION CHARACTERISTICS OF THE TROT

The trot is a symmetrical gait in which the two limbs appearing diagonally to each other perform exactly the same movement. In terms of speed, the average of the standardbreds monitored by Equimetre (for horses reaching 40km/h) shows a rate of 2.3 strides per second, with a stride length of 5.94m, compared to 1.3 strides per second and a stride length of 3m for classic horses.

The stride length of a trotter is limited by physiological constraints. Indeed, during each suspension time, the advancing hindleg risks to touch the front leg moving backwards. The hindlegs have to move forward from the outside in order to limit the interaction: as the two legs move on different lines, they are less likely to touch each other.

This lateral and physiologically abnormal movement for the horse is a loss of energy because the whole movement is not focused towards antero-posterior movement. Moreover, **this type of movement can lead to premature wear of the limbs and thus cause arthrosis, cartilage deterioration, etc.**

In specific situations, trotters may adopt unnatural gaits or gallop, which is then sanctioned. He may gallop forelegs and trot hindlegs (paddle), or vice versa (trap) or move simultaneously and in the same direction a foreleg and a hindleg on the same side (amble). The mechanisms leading the trotter to the fault are not necessarily documented in scientific research, but some situations such as fatigue or pain can trigger them.

The average of the standardbreds monitored by Equimetre (for horses reaching 40km/h) shows a rate of 2.3 strides per second, with a stride length of 5.94m, compared to 1.3 strides per second and a stride length of 3m for classic horses.

2 THE GALLOP AND THE PREFERRED FOOT

The gallop is an asymmetrical gait. It is common to hear that the horse «gallops on the right lead» or «gallops on the left lead».

These expressions reflect the way in which the horse places his limbs when galloping. The horse is said to «gallop on the left lead» when his left limbs (front and hind) move further forward than his right limbs.

The gallop is a three-beat gait, during which the horse simultaneously places the hind and frontlegs on his diagonal. In racing, horses are in a straight line and therefore have no strain: they can gallop on their «favorite lead».

Just like humans, horses are said to be «left-handed» and «right-handed». No studies have yet shown a difference in performance between right and left-handed horses. However, in a right-handed race, right-handed horses are more likely to win, and vice versa (Cully et al., 2018). In the United States, all tracks are left-handed, so the majority of horses are left-handed.

During a race, because of the speed, horses may be led to dissociate their movements. The horse's hindleg is set down slightly earlier than the foreleg associated with his diagonal. The gallop goes from three beats to four beats.

Just like humans, horses are said to be «left-handed» and «right-handed».

The advanced foreleg in canter is subjected to greater stress than the other. Indeed, it is the last limb to land before the glide and therefore supports, for a moment, the entire weight of the horse in an unstable position. When galloping on the right lead, the muscles of the right hand are more stressed than those of the left side.

As a result, right-handed horses will be stronger on the right and vice versa. Each horse is therefore asymmetrical due to his laterality. The trainer should take this preference into account in order to adapt the training to each horse.

With the exception of the departure stalls, thoroughbreds only very rarely adopt faulty gaits.

Sometimes the horse gallop may be unnatural for some time, due to the speed of his departure. A few meters later, the horse self-adjusts and re-adopts a normal gallop.

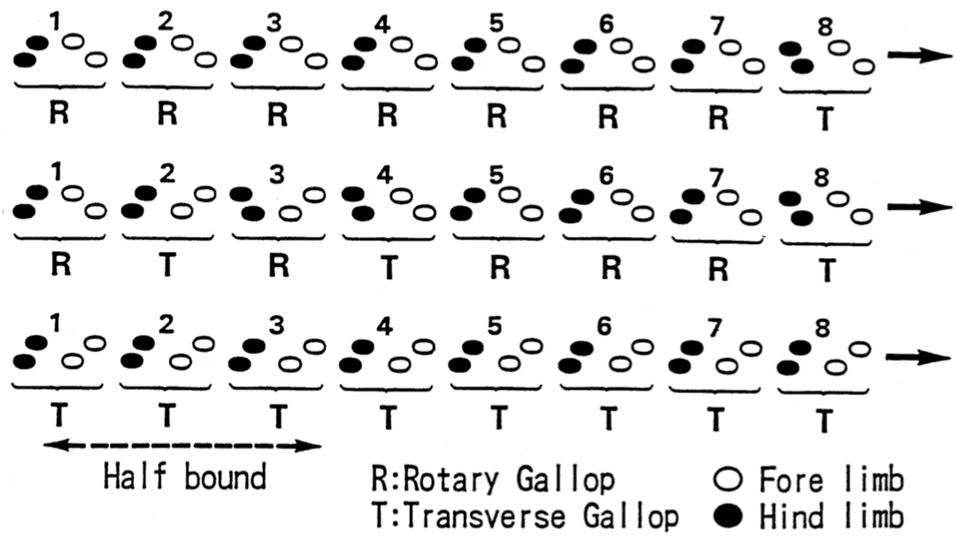


Fig. 5. Gait changes at the start dash in three horses.

This figure from Hiraga and Al. (1994) presents the locomotion out of a stall of 3 different horses. The first horse takes his first 7 strides at a loose canter, before returning to a classic right-handed canter. The second alternates between fair and disunited strides before stabilizing on the right. The third horse is in a classic left canter from the start.

It is advisable to take this preference into account when adapting the training and race entries of each horse.

3 THE HORSE'S BREATHING, ACCORDING TO HIS GAIT

Depending on his gait, the horse breathing rhythm is different. Therefore, breathing strategies are adapted accordingly to the horse's gait and speed.

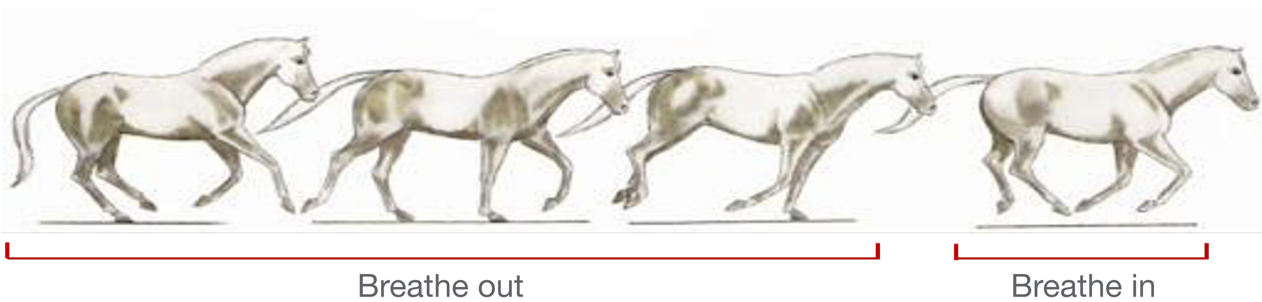
TROT

Breathing at trot is voluntary. It is not based on the change of posture and projection: the breathing cycle is independent from the movement. Like humans during a race, horses are able to breathe in and out over several strides. This allows trotters to adapt their breathing rhythm to their needs and speed. They can save themselves during flexible phases by decreasing their breathing rhythm and they can greatly increase their oxygen supply during intense times by increasing their breathing rhythm. The effort required for inhalation and exhalation is increased, they have to contract their muscles in order to make the air enter and expel it.

GALLOP

During canter, the breathing is based on the movement of the limbs: the horse breathes in during his suspension time and breathes out when his limbs are laid down. This synchronization varies very little with speed or fatigue, it is done mechanically.

The thoroughbred cannot adapt his breathing to the intensity of his effort because his breathing rhythm is necessarily based on the rhythm of his strides. He can only play on the volume of air he lets into his lungs. To breathe air more frequently, he has no choice but to increase his pace. The efforts made to breathe are reduced. Therefore, mechanically, when a horse needs to increase his heart rate, he is forced to increase his pace, reducing his stride length if needed.



Cycle of the horse's breathing in and out and correlation with the galloping stride

Mechanically, when a horse needs to increase his heart rate, he is forced to increase his pace, reducing his stride length if needed.

Fitness & locomotor profile

The fitter a horse is, the more he is able to push back his aerobic/anaerobic threshold, i.e., the point at which the energy requirements to cope with the effort exceed the oxygen supply capacity of the respiratory system. With training, the horse is able to hold his effort longer during his aerobic cycle. The cardio-respiratory management of his effort is improved, and he can then hold his stride length longer, without having to accelerate his pace to increase his respiratory frequency.

Furthermore, this specificity of breathing at gallop enables strategies to be put in place to save energy during the race. Indeed, when the horse changes foot, his projection time, and therefore his breathing time, is momentaneously longer. By changing foot, he can then catch his breath back thanks to the larger breath of air allowed by the longer suspension time and accelerate again afterwards.

CHAPTER 2 | THE SYMMETRY AND THE REGULARITY OF THE RACEHORSE

Although stride frequency and stride length are key parameters, objectivizing locomotion requires the mobilization of other resources. Indeed, other parameters can provide valuable information about how a horse moves.

Stride frequency and stride length provide information on how the horse accelerates.

Can we compare strides with each other? What can be the consequences of a lack of regularity or symmetry?

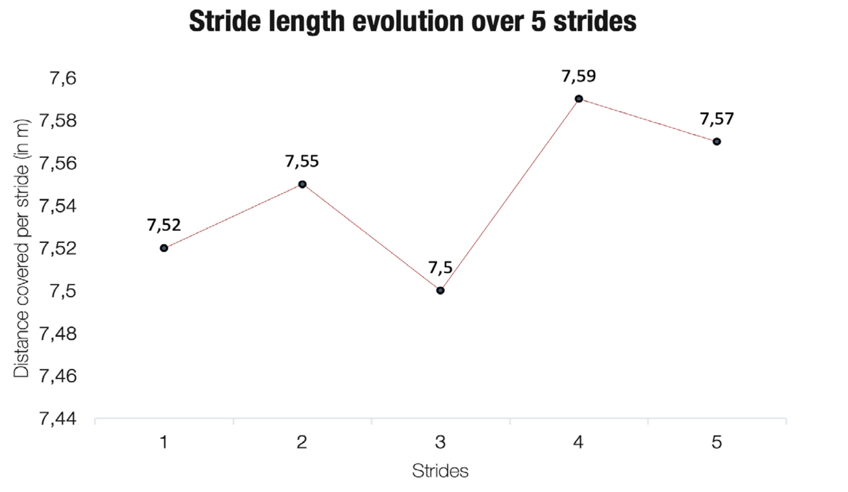
Any significant variation from one session to the next can be a warning to the trainer.

High-performing horses have good regularity scores, a sign of good balance.

1 REGULARITY, A GUARANTEE OF TALENT?

Regularity indicates whether the frequency of a horse's gait has changed greatly during training.

If one stride is compared with the next, they are never perfectly identical. No two consecutive strides are ever exactly the same in stride length or duration. Regularity allows us to study the variation in stride length and in stride frequency of a stride with the previous one.



By comparing the distance covered by 5 consecutive galloping strides, it appears that two strides are never exactly the same size, although they remain relatively close. In this example, the stride length would be 7m54 (by averaging all these values) but no stride is exactly 7m54...

The greater the difference between stride, the more energy the horse spends to maintain his pace.

A lack of regularity leads to a lack of efficiency and therefore to more effort for the horse.
Performance horses have good regularity indexes, a sign of good balance.

A horse regularity evolves with his age, training and is a sign of an improved coordination. At high speed, it is more difficult for the horse to maintain regularity as he approaches his limits.

Regularity, stride frequency and stride length are closely related: an increase in stride frequency leads to an increase in regularity. Indeed, as the strides are shorter and follow one another at a more sustained pace, the horse must maintain them in an almost identical manner in order to keep the pace. On the contrary, the longer the strides, the more the regularity decreases as it induces a movement further away from the horse center of gravity, which is difficult to control.

2 SYMMETRY, THE KEY TO PERFORMANCE?

Symmetry can only be defined when trotting as canter is an asymmetrical gait. It compares the movements of the right diagonal with those of the left diagonal. In canter, the two diagonals do not perform the same movements, so the symmetry cannot be calculated.

Horses being left or right-handed (cf.1.2), the thrust of the hindlegs is not identical on the left and on the right, due to the asymmetry of their musculature. In trot, the two diagonals must propel the horse forward in turn and are therefore subject to the force of the associated hindleg to perform the movement.

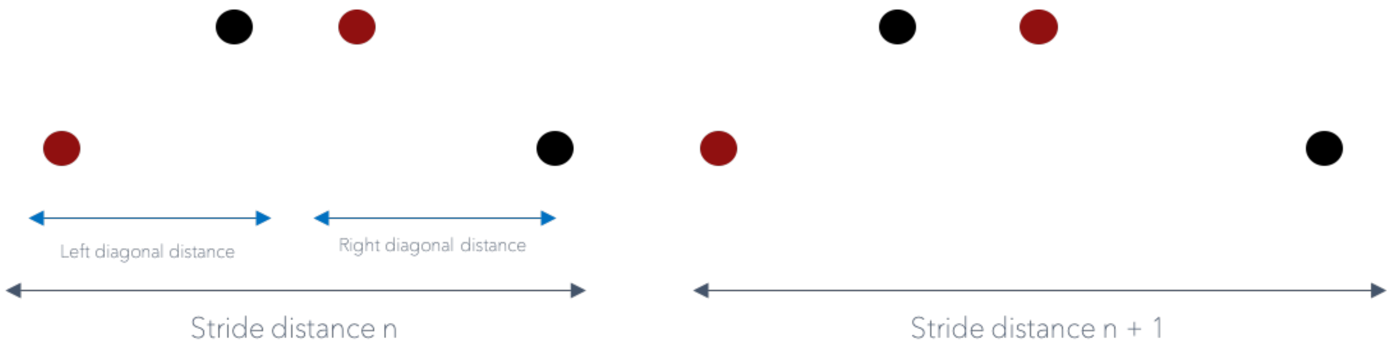
Symmetry measures the spatial and temporal variation that exists between the movement of the right and left diagonal. Ideally, both diagonals travel the same distance and result in the same glide time, in practice this is never verified. The foreleg-hindleg distance is variable, as are the hang times, laying times and distances travelled. Like regularity, symmetry improves with age and training.

IMPORTANT

A lack of symmetry leads to premature wear of limbs and hooves as horses must constantly compensate for the asymmetry of the gait.

Horses with little symmetry tend to lack balance, especially in the curves. A loss of symmetry is often observed at high speeds. Standardbreds are less symmetrical ridden than harnessed (LELEU, GLORIA, RENAULT and BARREY, 2010).

As the two diagonals do not perform the same movement, it is possible to measure this disparity in order to define the symmetry. Horses with defects in symmetry are on average less efficient and more prone to injury.



Regularity controls the difference in distance between one stride and the previous one. Symmetry controls the difference in distance between the right and left diagonal.

3 LACK OF REGULARITY AND SYMMETRY

Long-term monitoring of symmetry and regularity allows you to get to know your horses better, to check their progress or to detect pain.

However, it is important to keep in mind that a horse is never perfectly symmetrical or regular. As every horse is right or left-handed, he naturally has an asymmetry.

Well conducted training should improve the horse symmetry by promoting harmonious musculature and by trying to reduce natural disparities. To this end, it is useful to know which horse is right-handed and which is left-handed so that exercises can be adapted, and the horse morale can be maintained.

Monitoring these two parameters is therefore relevant. In addition to ensuring that the work is balanced, this also enables the early detection of possible injuries. In case of injury, in order to relieve the painful limb, the gait is modified to transfer weight to the healthy limbs. Regularity and symmetry are reduced. Any significant variation from one session to the next is a warning to the trainer. Based on the trainer's feelings and the horse veterinary history, objective data on symmetry and regularity inform the decision to investigate a possible injury and provide valuable information to the veterinarian if necessary.

In this way, training leads to an improvement in symmetry and regularity. Tracking these values and comparing them over time makes it possible to quickly detect a problem and check the effectiveness of the work.

Regularity and symmetry are therefore two key parameters in understanding a horse locomotion. Comparing one stride to another and the movement of the 4 limbs allows us to quantify the harmony and symmetry of the athletic horses' musculature.

CHAPTER 3 | LOCOMOTION STRATEGIES AND RACETRACK

The horse locomotion is strongly influenced by the track over which he moves. A racehorse moves differently on deep, hard, uphill, downhill, or flat ground. The quality of the ground as well as the type of track are key factors in the speed strategy of a racehorse. During a race or a training session, the impact of bends, slope and ground quality on the horse stride length and stride frequency can be evaluated.

1 THE BENDS

Straight and curved work are two different exercises. In a curve, the effort of the horse is greater than in a straight line because of the centrifugal force pulling him outwards. In order to maintain his way on the inside of the bend, the horse has to put in more effort. The adaptation of his locomotion to recover a natural balance requires a more intense effort.

Why do the curves involve a change in locomotion?
How stride length and stride frequency change?
Should curve training be supported?

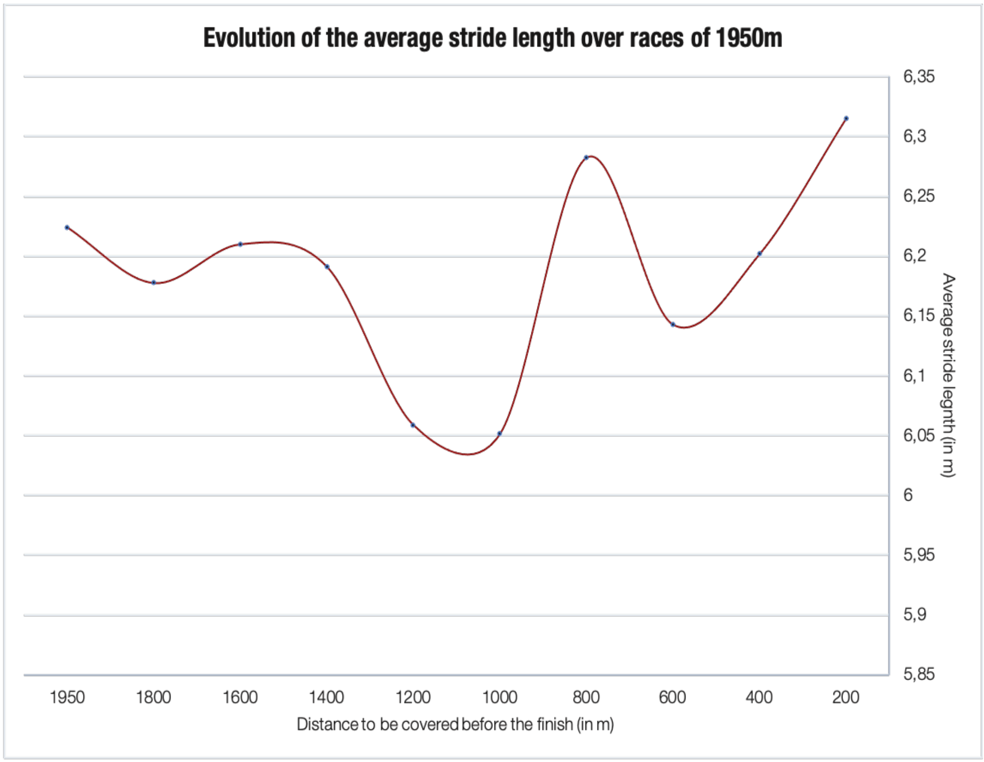
Restoring natural balance

When turning, the centrifugal force disturbs the horse balance. To avoid slipping, especially on hard ground, horses must change their locomotion.

The foreleg positioned inside the bend is then subjected to a higher pressure than the outside foreleg. All the muscles on the inside of the horse body are particularly stressed to prevent the horse from collapsing into the bend.

Speed reduction

It has been proven that the speed of a racehorse tends to decrease when turning. When turning, the required effort increases, and it forces the horses to slow down in order to hold on over time. The stride length decreases sharply while the decrease in pace is less important. As the muscles are subjected to a greater effort, they are no longer strong enough to maintain a stride length equal to the one of a straight line.



In training, the work on the bends then appears to be relevant. This exercise enables the development of specific muscles and trains the horse to adapt his locomotion. The improvement of his mobility will avoid any contact between his limbs (which could put the horse at fault).

2 THE SLOPE

Whether at the racecourse or on the training tracks, there is always small elevation gains.

Why does the horse adapt his locomotion to the slopes? How is this change perceived in the data? Is training with slope beneficial for horses?

Whether uphill or downhill, slopes necessarily induce a change in the horse locomotion.

Uphill Track

On positive elevation gains, the effort required of the horse is greater than on flat ground: he must overcome the gravity which tends to prevent his progress.
The higher the elevation gain, the more intense the effort. The horse stride length decreases sharply due to the extra force required to cover the same distance as on the flat part of the track.

If the horse expends equal energy, his pace and his stride length will be slower uphill than on flat ground.
On the other hand, if the horse accelerates uphill, he increases his pace, but his stride length remains the same.

Training horses on uphill slopes allows them to work on a large effort without reaching maximum speed. **The horse develops his power and musculature.**

Downhill track

On the contrary, going downhill, the main challenge is to control the horse balance. The forehand is overloaded by the weight of the horse.

Downhill training is not necessarily recommended as no demonstration has been made as to the possible improvement in horses on this type of exercise. Some scientists hypothesize that such training could lead to injury.

		Gait	Distance meters	Time min	Pace km/h	Average HR bpm	Average tilt %	Stride Length meters	Stride Freq. stride/s
▼	7	Gallop	1370	01:55.0	42.9	139	1.6	5.3	2.34
			170	00:14.0	43.7	135	-6.3	5.87	2.27
			200	00:15.3	47.0	134	-3.5	5.80	2.27
			200	00:15.6	46.0	133	-1.5	5.74	2.24
			200	00:16.0	45.0	132	2.6	5.38	2.26
			200	00:15.0	48.0	147	8.0	5.41	2.49

		Gait	Distance meters	Time min	Pace km/h	Average HR bpm	Average tilt %	Stride Length meters	Stride Freq. stride/s
▼	8	Gallop	1460	02:17.0	38.4	196	1.4	5.3	2.16
			60	00:17.0	12.7	143	-4.4	1.96	1.64
			200	00:18.0	40.0	191	-5.4	5.51	2.06
			200	00:17.5	41.1	205	-2.9	5.56	2.08
			200	00:17.5	41.1	212	-1.0	5.42	2.10
			200	00:16.3	44.1	217	3.0	5.59	2.19
			200	00:15.6	46.0	221	8.6	5.33	2.36
			200	00:15.6	46.0	188	6.4	5.29	2.44
			200	00:19.3	37.2	157	2.6	5.26	2.03

CASE STUDY

In the following example, the exercise carried out starts on a downhill slope, continues on a false flat before ending on an uphill. The horses were asked to accelerate on the uphill slope. Indeed, they reach their maximum stride length in the false flat at the end of the downhill slope. However, they are forced to reduce it during the ascent due to the strain on the muscles. As their pace increases, they are forced to accelerate slightly. This example highlights the fact that neither horse is able to maintain his stride length during a climb. If both horses are able to increase their pace to accelerate uphill, the descent can be difficult to negotiate. The data shows that the number 1 horse decreases his pace in order to restore his balance.

It is possible to explain that the stride length continues to decrease even though the slope is gentler (going from 8.6 to 6.4%) by a «fatigue effect»: the muscles put to the test during the shift to 8% need a little more time before they are able to function normally.

3 THE GROUND

Bends and elevation gains influence the speed and locomotion of racehorses. However, we can add the influence of the ground on which the horse progresses to these parameters. In Europe, the tracks are mainly grass or all-weather tracks. Training tracks can be made of sand.

What are the characteristics of the different tracks?
Why does the horse change his locomotion according to the terrain?
How do stride length and stride frequency differ according to the type of ground?

Grass tracks

The grass slopes are very weather dependent. Temperature and precipitation strongly influence their quality. When the circumstances are optimal, they allow good stride damping, short laying time and remarkable peak speeds.

All-weather tracks

Synthetic slopes experience very little variation with the weather; however, their quality is far from equal to that of natural slopes.

Hard slopes

Particularly hard tracks allow the horse to be propelled with less energy. The horse then develops a large stride length and a high stride frequency. However, tracks that are too hard are not always those allowing the horse to reach the highest speeds. The shocks are not damped, which can be painful for the horses.

Deep tracks

Deep tracks, on the other hand, make it difficult for the horses to progress. Their speed decreases due to the reduction in pace and in stride length.

The type of ground on which the horse moves influences not only his speed but also his locomotion. Generally speaking, at a constant speed, the harder the ground, the longer the strides will be. Conversely, the deeper the ground, the shorter the duration of a stride.

Ground condition	Average Stride Frequency	Average Stride Length
Light	2,38	7,62
Good	2,37	7,53
Good to soft	2,37	7,47
Soft	2,33	7,28
Sticky	2,32	7,02

This table shows the average stride frequency and stride length of galloping races as a function of the depth of grass tracks. The stride length and the stride frequency are therefore correlated to the quality of the track. Both stride length and frequency decrease as the depth increases: horses run slower in mud than on very hard ground.

CHAPTER 4 | LOCOMOTION AND SPEED

APTITUDES

In racing, a horse speed seems to be the most important factor in his success. Each one has his own specific stride, which defines his speed aptitudes. To increase his speed, the horse increases his stride frequency and stride length.

Does stride length change in the same way as stride frequency? How do horses adapt their stride length and stride frequency to a given speed?

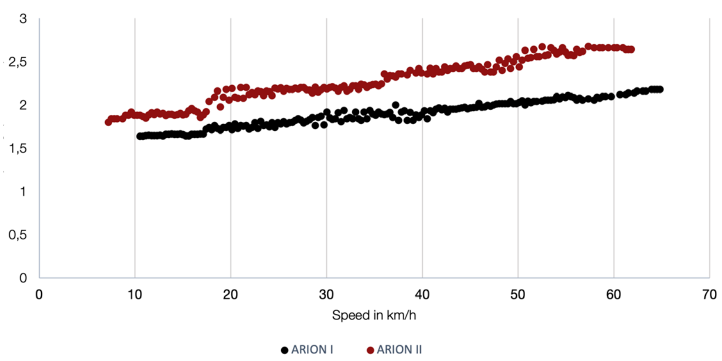
1 LOCOMOTION AT THE ORIGIN OF SPEED

A horse pace increases linearly with speed until he reaches a maximum speed. The stride frequency can vary in the same way from 25 to 30km/h as it does from 55 to 60km/h.

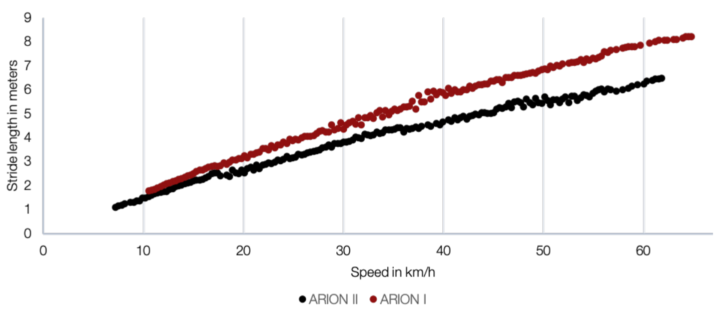
On the contrary, stride length does not evolve linearly. Its evolution depends on the speed and it will be more important for low speeds than higher speeds. At high speed, a variation in stride frequency will produce greater acceleration.

The graphs showing the stride frequency and stride length as a function of speed are specific to each horse. Each curve describes how the horse accelerates and how the frequency and length of the strides change. Each horse is unique, and his locomotor profile is a valuable help to discover his potential or decide what distance to race him.

Comparison of the stride frequency depending on the speed for two horses



Comparison of the stride length depending on the speed for two horses



We compared two horses monitored with Equimetre. These two horses have very different locomotor profiles. We can see that Arion I trains at a very fast stride frequency while Arion II trains at a very wide stride length. These graphs show the stride length and stride frequency curves as a function of speed for two horses: ARION I and ARION II.

2 ACCELERATION STRATEGIES AND LOCOMOTION

During a race, horses are exposed to many changes of rhythm. These changes are influenced by the track, the race pace or the will of the jockey. This leads the horses to constantly adapt their locomotion. They must be able to accelerate or slow down according to the circumstances. These changes should be quick and consume little energy.

The following graph (HIRAGA, YAMANOBE and KUBO, 1994) shows the evolution of stride frequency and stride length for the first 30 strides at the start of a race. If the stride frequency reaches its nominal value from the beginning, the acceleration is made thanks to the progressive increase of the stride length during the first 20 strides before stabilizing.

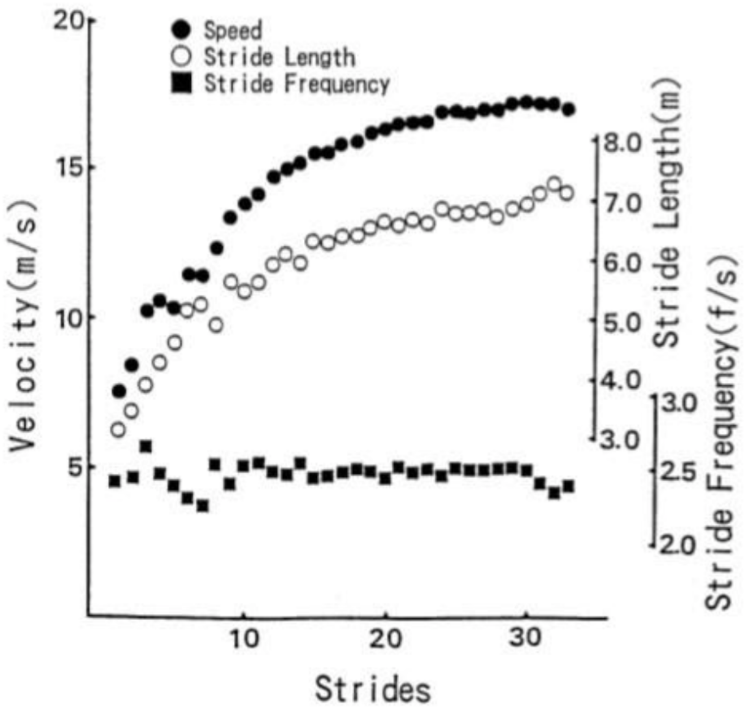


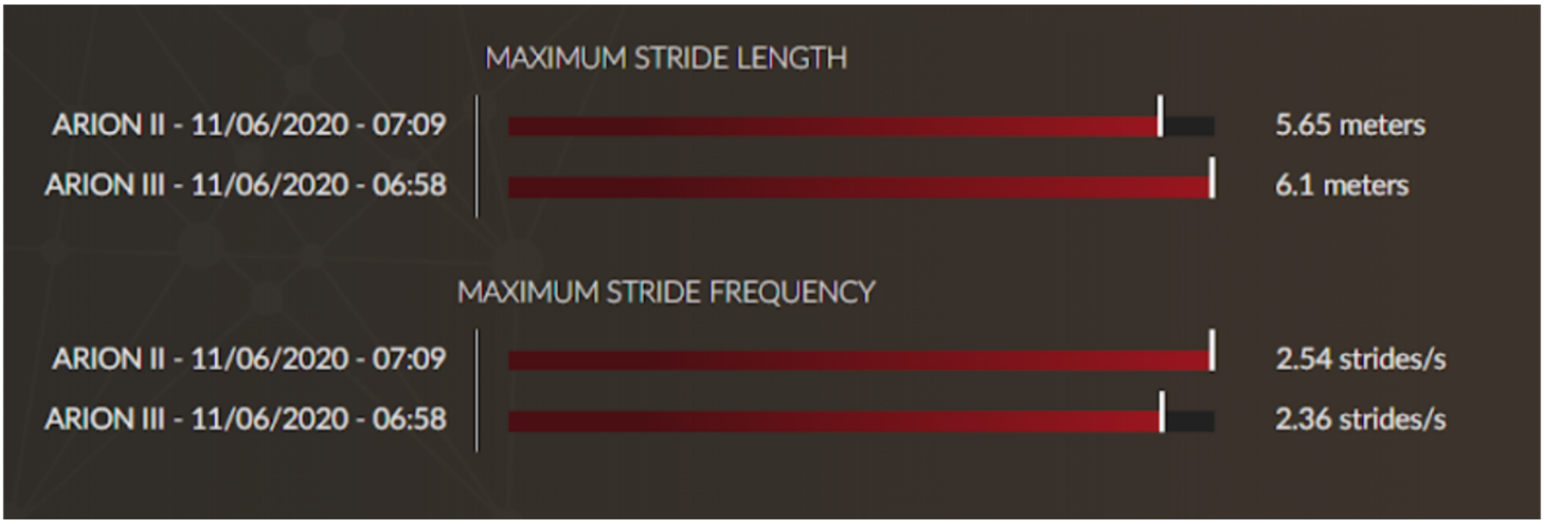
Fig. 2. Changes in velocity, stride length and stride frequency at the start dash in a horse.

FUN FACT

When the rider stimulates the horse with a whip, there is a reduction in the length of the strides and an increase in their frequency. However, speed is not significantly influenced. The use of the whip affects the horse locomotion strategy rather than speed (Deuel and Lawrence, 1988)!

By studying the training data on several horses, we can see that depending on their speed, the pace and stride length do not vary in the same way. During the deceleration, the stride frequency tends to be lower for the same speed than during the acceleration.

When the speed changes during a race, horses spontaneously adopt the stride frequency-stride length pair they prefer. As two horses can progress at the same speed with different stride frequency and stride length, a horse may prefer a wide stride length but with a longer stride time (slower stride frequency) or, on the contrary, a very fast stride but not very wide. By comparing a horse with the average at a given speed, it is possible to determine if the horse prefers to race in stride frequency (he makes faster strides than the average) or in stride length (his strides are larger than normal).



Change in stride length and stride frequency according to the racehorse profile for the same speed - Data from the EQUIMETRE platform

In this example, Arion II is galloping at s=5.65m (stride length) × 2.54st/s (stride frequency)=14.3 m/s (or 51.5 km/h) while Arion III is also galloping at s=6.1m (stride length) × 2.36st/s (stride frequency)=14.3 m/s.

Nevertheless, these two horses have completely different strategies: Arion II favors stride frequency and Arion III stride length.

3 HOW TO DETECT FUTURE PERFORMERS THANKS TO LOCOMOTION DATA?

It may seem obvious that the greater the horse stride length and frequency, the faster he is. However, this is not always true. Indeed, horses having a very high speed peak do not always win. The jockey must choose a strategy that matches his horse's locomotor profile.

What is a good stride?
What is the reference among great champions?
How to get the most out of a horse according to his locomotor profile?

Scientists have managed to bring to light common points specific to horses with optimal stride efficiency.

Among them

- Low contact time with the ground
- Little upward bounce
- A great distance covered during the flight time

To these are added for thoroughbreds:

- A greater dissociation of the diagonal (almost 4 times in the canter stride instead of 3)
- A reduction in the time where two members touch the ground together

The idea that a good horse necessarily has a wide stride is a myth. Although Secretariat or Black Caviar had respective stride lengths of 8m20 and 8m50, Winx's stride length was only measured at 6m80. However, her stride frequency was quite outstanding: she could perform up to 2.8 strides per second! On specific distances, a very high pace is a real asset. Smaller differences can be found in standardbreds. Bold Eagle has an amplitude of 6m40. However, he can perform up to 2.8 or 2.9 strides per second! Timoko relies more on his stride length exceeding 6m70 than on his stride frequency of 2.5 strides per second.

Depending on the locomotor profile of each horse, the entry distance and the race strategy differ. A horse with a great stride length should start the sprint from a distance to allow him to reach his maximum speed by giving him time to increase the size of his strides to their maximum.

On the contrary, a horse with a high stride frequency should wait until the last moment because the maximum speed will be reached quickly. A sprint starting from a far distance may exhaust the horse, who would no longer be able to maintain his pace during the last few meters.

To sum up, a wide stride length is not "better" than a high stride frequency. It is rather a question of making the best use of the strengths of each horse.

To conclude, each horse increases his stride length and stride frequency differently according to the desired speed. This evolution reflects the locomotor profile. Horses adapt their locomotion to a new speed by first changing their stride frequency. Whether a horse prefers to train in stride length or stride frequency is of little importance as long as the racing strategies are adapted.

CHAPTER 5 | IMPROVING RACE MANAGEMENT THROUGH LOCOMOTION

Even though they are in the best physical condition, horses may experience temporary fatigue and a drop in performance.

Several factors can induce tiredness, such as a significant decrease in energy reserves, muscle fatigue or an accumulation of lactic acid in the muscle.

In addition, the cardio-respiratory system is also pushed in order to continue to supply oxygen to the body and muscles. The heart rate then remains very close to its maximum for a considerable period of time. As the race progresses, depending on the distance, the horses adopt various locomotor strategies to optimize their efforts.

How do the stride frequency and stride length evolve throughout the race?
Are there any differences in locomotion depending on the distance of the race?
How do you spot a horse thanks to locomotion?

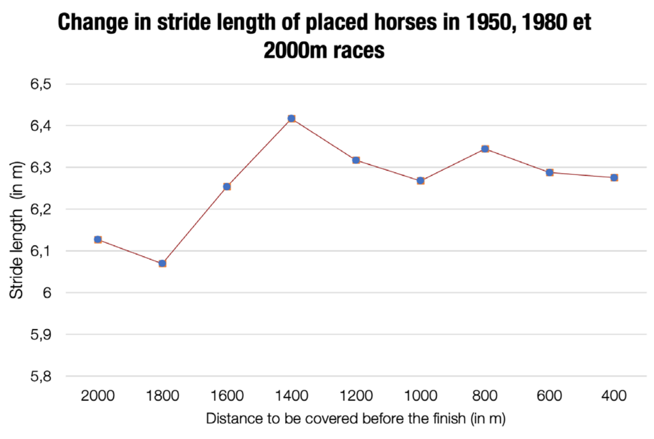
1 HOW DO HORSES ADAPT THEIR LOCOMOTION DURING A RACE

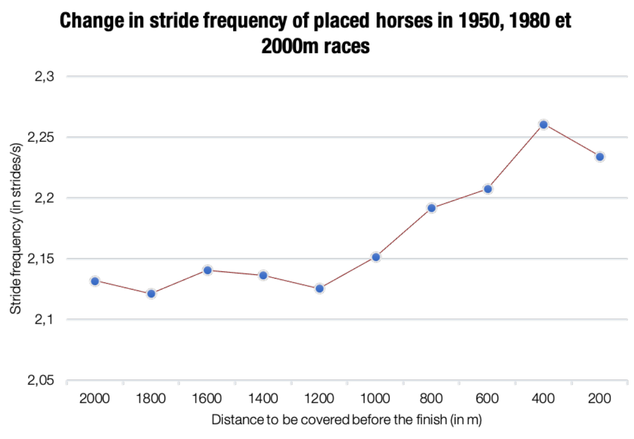
Maintaining a high pace requires an efficient cardio-respiratory system, especially at canter where breathing follows the same rhythm as the stride. When a horse stride frequency increases, his breathing follows the rhythm of the strides. In long-distance races, maintaining a high pace throughout the race while keeping sufficient breath is particularly difficult. The horse is then forced to maintain a very high breathing rate, which can cause premature shortness of breath.

To maintain a high speed over long distances, the horse must therefore rely on the size of his strides. A large stride length is less demanding on the cardio-respiratory system. Nevertheless, the muscles must be prepared for this effort, as they are put under greater strain in terms of power. In the last 200m, if the horse is still able to do so, he tries to sprint by increasing his stride frequency and stride length.

This ideal situation may not be respected in a race, considering the type of ground, the race pace and the position in the race.

When there is a sudden change of pace during the race, horses tend to adapt to this new speed by changing their stride frequency as it is particularly quicker to increase or decrease the length of a stride than its size. This is why the best sprinters are usually horses that can easily adjust their pace.





In the following example, it is possible to study the locomotion of standardbreds who finished in the top 3 in races of 1950, 1980 and 2000m. The average stride frequency and the average stride length for each 200m interval have been plotted. We notice that the horses decrease their stride frequency and stride length after the start: once well positioned, they hold their speed, to strongly increase their stride length in the last 400m in order to take the advantage. On the other hand, if they are able to increase their pace at first, they are not able to maintain it until the end: after having increased their pace, they rely on their stride length to ensure themselves a place at the finish. Variations in stride length during the race are linked to the bends.

2 A LOCOMOTION STRATEGY FOR EACH DISTANCE

Depending on the distance of the race, speed will be different. On the first hand, short distances require the horses to give their maximum and to accelerate very strongly over the last 200 meters. Longer races, on the other hand, require a more advanced management of the horse resources in order to preserve his strength until the end of the race.

The distance of a race influences the speed and therefore the locomotion. However, at equal speed, the winning locomotion strategy differs according to the distance. The last 200 meters are heavily impacted by the distance of the race.

In order to compare the locomotion of two horses that have run different distances, it is impossible to compare only their maximum stride frequency or stride length. Comparing the locomotion at the speed achieved in the two races provides more interesting information about the locomotor profile of these horses.

As the distance increases for the same speed, the horses tend to make larger strides and reduce their pace. This relieves the strain on their cardio-respiratory system which is already strained by the intensity of the effort. In addition, in a short distance race the pace is higher.

Over short distances, it is more efficient to rely on a fast pace to reach a high speed because reaching a maximum stride length requires more time. The speed is reached more quickly and gives an advantage to win.

Using a database from New Zealand, the Arioneo team has calculated the average stride frequency and stride length of horses classified as trotting in harness over specific distances. In order to make comparison, the locomotion used is taken at 50km/h.

Distance	Average stride frequency at 50km/h	Average stride length at 50km/h
1600	2,36	5,93
2000	2,25	6,16
2400	2,24	6,16
2600	2,22	6,23
3200	2,20	6,23

Between 1600 and 3200m the pace drops by 7% while the stride length oppositely increases by 7%. As expected, the stride frequency decreases with distance to relieve the cardiorespiratory system while the stride length increases to maintain a consistent speed.

Distance	Average stride frequency at 60km/h	Average stride length at 60km/h
< 1200	2,38	7,17
1600 - 1800	2,31	7,25
2000 - 2200	2,29	7,26
2400 - 2600	2,29	7,30
> 3000	2,27	7,28

As for the trot, this table summarizes the average stride frequency and stride length of the gallopers at 60km/h according to the running distance. It can be noted that here again, the average stride frequency decreases while the distance increases as opposed to the stride length, which increases with the distance.

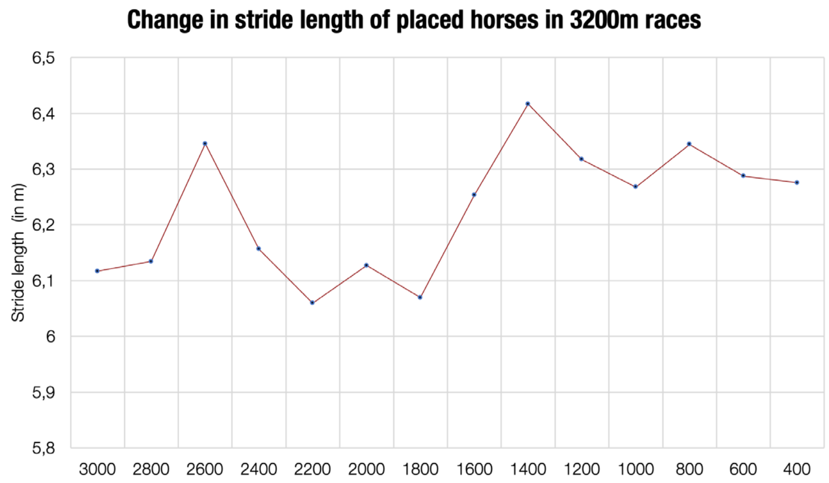
It appears that horses with a high stride frequency tend to win over shorter distances. On the contrary, horses with a wide stride length perform better over longer distances.

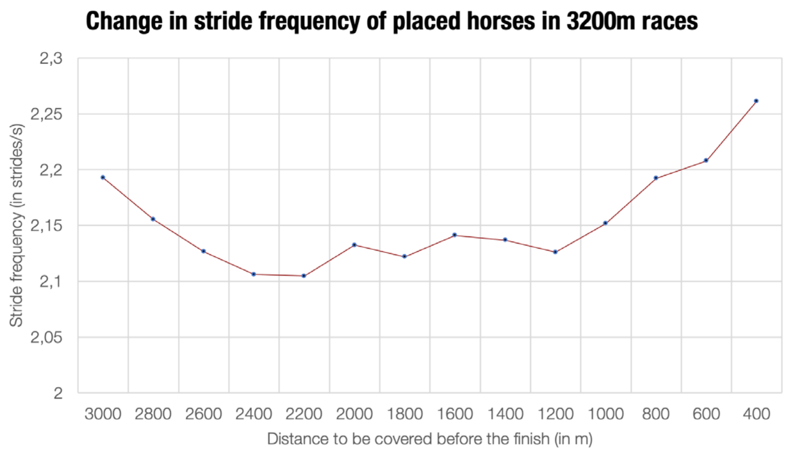
The race distance influences the finish. Depending on this length, locomotion in the last 200 meters is clearly different. During a long race, the muscles are often tired from the effort they have made. Some horses then produce lactic acid, a waste product which diminishes their performance and forces them to reduce their stride length in order to relieve their muscles. Some can no longer increase the size of their stride in the last 200 meters. In the worst-case scenario, they may be forced to reduce their stride.

The best horses are the ones able to accelerate by increasing their pace only as long as their cardio-respiratory system is still able to adapt to the effort required. On the contrary, we have seen that over very short distances, the horses increase their pace and stride length during the last 200 meters.

The distance of the race influences the stride length and stride frequency selected by a horse. As fatigue appears, the horse adapts his locomotion strategy in a global way during the race but also during the last 200 meters.

Fatigue is therefore the cornerstone of locomotion adaptation for racehorses.





We can see a decrease in pace after the start of the race: once placed, the horses save their energy. During the race, they keep their pace almost constant: slight variations are due to the bends (this can also be seen in the stride length, which changes more). At 800m, they accelerate the race train as shown by the sudden increase in stride frequency. Although the stride length is not yet modified, it remains high. Finally, in the last 200m, the stride frequency increases sharply while the stride length collapses. Horses wait longer to increase their stride frequency, as their muscles are more tired than in a fast race. The race train before the last 600m is only slightly elevated: the difference between the horses is at the finish where only the fittest horses hold the stride length. Here again, an increase in race speed is followed by an increase in stride frequency for the finish.

3 WHAT IS THE IMPACT OF TIREDNESS ON THE LOCOMOTION OF A HORSE DURING A RACE?

In addition to the changes in stride length and in stride frequency which occurs according to the duration and intensity of the race, other parameters are also affected by the effort. If a tiredness related to the horse cardio can only influence his stride frequency, a muscular tiredness induces other adaptations that can be the cause of injuries.

When muscles accumulate too much organic waste (especially lactic acid), they lose efficiency. In addition, a lack of oxygen deprives the brain of a valuable resource. Horses are no longer able to maintain a regular stride because the nervous system is no longer sufficiently oxygenated to continue to regulate the body. The muscles no longer catch up as well with the irregularities of the ground.

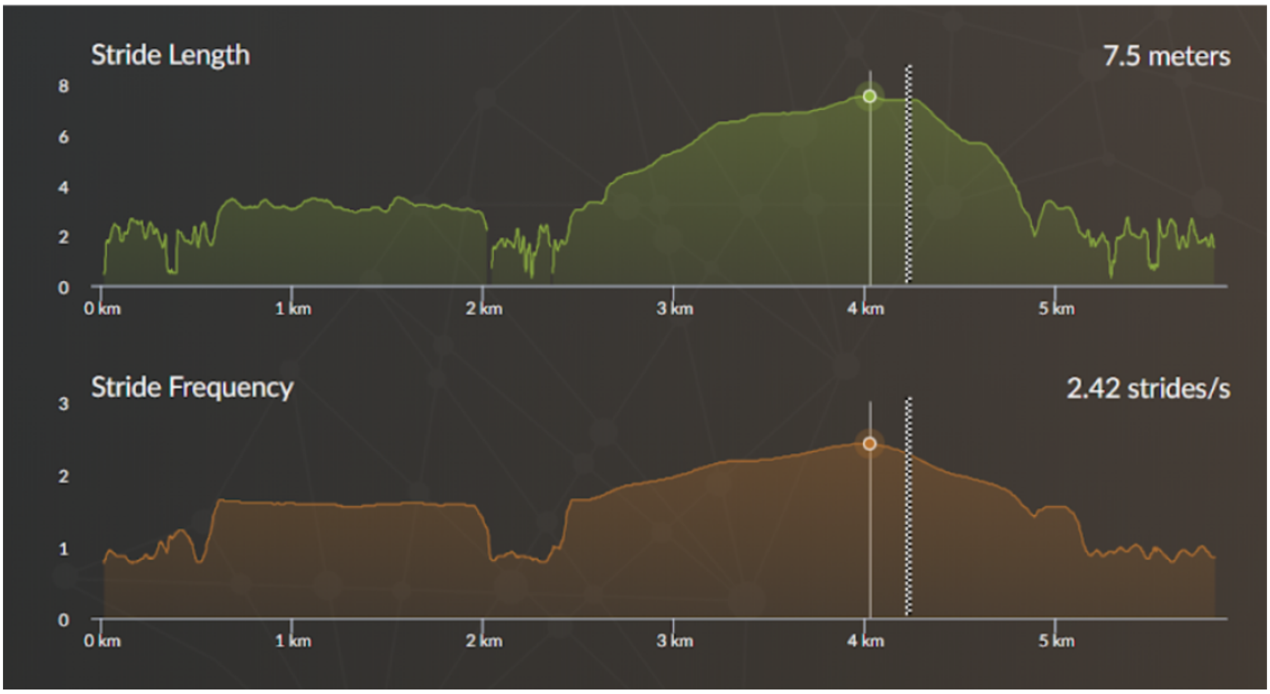
This will result in a decrease in regularity and symmetry in trotters.

In order to distribute their effort, it is common to see gallopers change feet. Indeed, galloping on the right side of the leg puts more strain on the right diagonal, the muscles in the right diagonal are then more under stress and vice versa.

Therefore, the horse changes foot as the race progresses in order to rest the two diagonals successively and to create a uniform fatigue on the muscles of his forelegs. It is unusual for a horse to run the whole race on the same galloping foot. Moreover, inspiration comes during the projection phase of the gallop. When changing feet, this projection phase is slightly longer. Therefore, a change of foot allows for the «breath of fresh air» necessary to mark a break during the race, and regain stamina.

A change of foot allows for the «breath of fresh air» necessary to mark a break during the race, and regain stamina.

Horses adapt their pace and length as the race progresses. A high stride frequency allows them to reach a maximum speed quickly but puts a strain on the heart. A high stride length works the muscles and saves breath.



▼	8	Gallop	2160	02:56.0	44.2	207	0.0	6.2	2.11
			175	00:23.0	27.4	180	0.1	4.3	1.81
			200	00:21.0	34.3	192	1.0	5.0	1.91
			200	00:16.5	43.6	204	-0.4	5.8	2.06
			200	00:14.1	50.8	211	0.3	6.5	2.17
			200	00:13.3	54.0	214	0.2	6.8	2.21
			200	00:12.2	58.8	215	0.4	6.9	2.30
			200	00:11.2	64.0	215	1.2	7.3	2.40
			200 - Finish	00:11.5	62.6	217	-1.3	7.4	2.36

Over long distances, horses tend to prefer a wide stride, allowing them to save themselves for the final sprint. However, in long races, it is not uncommon for horses to be unable to maintain their stride length. With fatigue, the regularity of the strides diminishes, as does their stride length and/or stride frequency.

CHAPTER 6 | ANALYSING LOCOMOTION TO PREVENT THE RISK OF PATHOLOGIES

Analyzing the locomotion of your horses allows you to detect injuries or warning signs of pathologies. Indeed, if a limb is discomforting, the horse adapts his way of moving in order to reduce his pain.

How does the data collected by EQUIMETRE enable locomotion pain to be detected? What situations require vigilance from trainers?

1 DETECTING INJURIES AND EMERGING LAMENESS WITH LOCOMOTION ANALYSIS

Successfully diagnosing pain before it turns into an injury is one of the main goals of EQUIMETRE.

How are locomotion parameters changed as a consequence of pain?
How do regularity and symmetry data evolve?

Symmetry monitoring to detect future lameness

A horse in pain changes his gait and locomotion in order to relieve his injured limb. The aim is to limit the efforts borne by the limb, in terms of duration and weight supported. In order to reduce the support time, the limb is put down only for a brief moment before being lifted. A suffering horse compensates with the other side by shifting his weight. He is therefore no longer symmetrical.

Increase in stride frequency: an interesting warning

An increase in stride frequency can be linked with pain. Indeed, if a limb is painful, the horse will not put in all the power necessary to maintain a good stride length and will have to rush to maintain the required speed. On top of that, symmetry and regularity deteriorate. When trotting, the deterioration of symmetry is particularly striking. The diagonal of the injured limb has a very reduced time on the ground in comparison to the one not injured. The two diagonals no longer perform the same work. The regularity brings less indications. Monitoring the symmetry value of a young horse makes it possible to know his reference level and to be able to monitor the beginning of discomfort in a horse.

Any abnormality of stride frequency or stride length must be investigated. In order to accelerate, the horse prefers to increase his pace by trying to limit his stride length as much as possible (Barrey, Auvinet and Couroucé, 1995). If at a given speed the stride frequency is much higher than usual, this may be a sign of an underlying problem that should be investigated if the situation does not improve.

2 PREVENTING RISKS THROUGH BALANCED TRAINING

There are situations in which specific locomotion may represent a risk. Knowing these situations and which horses are more likely to be affected allows for better risk control.

Monotonous training promotes the risk of locomotor pathologies. Knowing which exercises are risky and which horses are more likely to be affected is great to conduct prevention work.

At gallop, how can the track hand be a risk following the lateralization of the horses? Why is a large natural stride length a risk factor?

Track hand VS favorite galloping

We saw that each horse has a preferred galloping foot. The foreleg associated with this side is therefore more trained than the other as the horse gallops more often on it. This foreleg is less fragile because it is stronger (Rooney, 1983). However, the galloping foreleg is subject to significantly more stress and this is particularly true in the turns (Cogger et al., 2006). As soon as the horse changes feet to be on the side where he is least comfortable, his risk of injury is increased. Running a right-handed horse on a left-hand track also presents more danger than if the horse had been left-handed. During the left turn, the left foreleg will be under greater stress than the right foreleg. However, the left foreleg is also more fragile than the right and injury could occur.

The large natural stride length requires a powerful musculature.

A large stride length, although beneficial in the race, is also to be handled with care. As the limbs land further from the body and faster, the forces applied to them are also greater. As the forces on the limbs are greater, there is a greater risk of injury. Trainers should wait until young horses or horses returning to training have had time to build up or rebuild their muscles properly before asking them to go too fast.

Therefore, the choice of the track hand is essential to give the best results but also to preserve horses. Asking for maximum speeds to young horses or horses lacking strength can be dangerous especially if they have a large stride length which is one of the main risk factors identified.

CHAPTER 7 | HOW TO IMPROVE LOCOMOTION WORK BY EXPLOITING EQUIMETRE

1 CHOICE OF DISTANCE ACCORDING TO LOCOMOTOR PROFILE

The parameters of stride frequency and stride length have an immediate impact on the fatigue felt by the horse. It is therefore possible to determine on which races to run the horses by observing their locomotor profiles.

How does locomotion influence race entry strategies?
How can the optimal distance for a horse be determined using his locomotor profile?
What strategies should be adopted during the finish?

Stride length and stride frequency do not use the same energy channels. If the stride frequency allows sudden accelerations, a high one cannot be sustained for long.

On the other hand, stride length requires more time to develop. Once reached, the horse has less difficulty maintaining a full stride. Accute knowledge of the locomotor profile is therefore essential in order to make the best choice of race entry according to the distance.

When choosing between entries, a distinction must be made between locomotion in the race train, which influences the choice of race, and maximum locomotion, which influences the strategy during the finish.

The first thing to know is the pace of the race being aimed at, which is around 65 km/h at canter and 1m12s per kilometer at trot.

The next thing to determine is the pace and stride length of the horse at that speed. A comparison of his reference values will then give a precise indication of the most suitable distance.

If the stride frequency is too high in relation to the distance, the horse may get tired very quickly and will experience difficulties finishing the race.

Otherwise, if the pace is too low for the distance, the horse may not be able to deploy all his resources and may be subject to the variations in pace of his opponents. It is also important to keep in mind that if the race rhythm is too far away from the rhythm the horse is comfortable with, he is forced to adopt a stride length and stride frequency that are too far from his own. He may get tired excessively for an exercise that should be easy for him.

2 RACE STRATEGY AND LOCOMOTION MANAGEMENT

In order to develop a winning strategy during the last 600 meters, knowledge of the maximum values of stride length and stride frequency, as well as the values of locomotion in the race provide valuable clues.

First of all, it is a question of knowing the horse stride frequency and stride length at his maximum speed. By comparing these values with the average values during the finish of the targeted races, it is possible to find out whether a horse has a better stride length or a better stride frequency than the other competitors. Horses with a better pace can afford to wait until the last moment to sprint because they will reach their maximum speed very quickly, while horses with a high stride length will have to be launched from further away in order to reach their maximum speed. These values must however be weighted by the difference between the maximum and the race values.

Depending on the effort required, the horse preferably increases his stride frequency or stride length. Studying the stride length and stride frequency of a horse at the racetrack can be a valuable aid in choosing entry distances. The maximum stride length and stride frequency are, in turn, decisive in the development of the finishing strategy.

Let's take the example of two horses with completely different locomotor profiles, ARION I and ARION II.

	ARION I	ARION II
Stride Frequency at 60km/h	2,5	2,1
Stride Length at 60 km/h	6,65	7,9
Max Stride Frequency	2,7	2,2
Max Stride Length	6,85	8,3

Comparing the 60km/h values of ARION I and ARION II with the race averages, it appears that ARION I has a very high stride frequency which should give him an advantage in very short races of around 1200m. On the other hand, ARION II has a very low stride frequency which he compensates with a high stride length. Longer races should be in his favor.

Distance	Average stride frequency at 60km/h	Average stride length at 60km/h
< 1200	2,38	7,17
1600 - 1800	2,31	7,25
2000 - 2200	2,29	7,26
2400 - 2600	2,29	7,3
> 3000	2,27	7,28

Once the distance has been chosen, the finishing strategy will be different. ARION I has a maximum stride length very close to his racing stride length (less than 20cm apart), so he can wait before launching the sprint and keep the pace by increasing his stride frequency. On the other hand, ARION II has a maximum stride length higher from his racing stride length, which is why the sprint should be launched from a distance to allow him to deploy his strides.

Depending on the effort required, the horse preferably increases his stride frequency or stride length. Studying the locomotion parameters of a horse at the racetrack can be a precious help in choosing the distances of the race.

ARIONEO

EQUIMETRE

Equine technology dedicated to the racehorse's training

CARDIO

HEART RATE
RECOVERY

LOCOMOTION

STRIDE LENGTH
STRIDE FREQUENCY

SPEED

SPEED
SPLIT TIMES
GPS

WHY EQUIMETRE ?

- Performance and health management
- Analysis of physical aptitudes for race entries
- Underperformance investigation
- Racehorses' comparison
- Detection of future performers

"*Racing has always been a sports of opinions: that's what it's based on. I've always been wanting to push the boundaries of "why" that opinion is the right decision or the wrong decision. By curating a sports science division, we've made a commitment to this, and we're already starting to see the results on the track.*"

Ciaron Maher
Top 3 Australian Trainer in 2020
G1 Cox Plate Winner

TO FIND OUT MORE PLEASE CONTACT A MEMBER OF OUR TEAM

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STRIDE DATA ANALYSIS - EVERYTHING YOU SHOULD KNOW

RACEHORSE'S LOCOMOTOR PROFILE

We will call **«Locomotor Profile»** the stride frequency and stride length pair of a horse at a given speed (60 km/h for thoroughbred). If the locomotor profile is more or less based on stride frequency or stride length, the racing abilities will be different.

	Sprinter	Miler > 1600m	Stayer > 2400m
Stride frequency (Strides/second)	More than 2.43	Less than 2.4	Less than 2.35
Specialities	A high stride frequency allows you to reach maximum speed more quickly than a long but infrequent stride.	Since speed is achieved through a longer stride, horses that will have locomotor skills specific to longer distances are distinguished by a wide stride length and a low stride frequency, allowing them to hold their speed.	

LOCOMOTION STRATEGIES AND RACETRACKS

The bends

In a curve, the effort of the horse is greater than in a straight line because of the centrifugal force pulling him outwards. In order to maintain his way on the inside of the bend, the horse has to put in more effort. The adaptation of his locomotion to recover a natural balance requires a more intense effort.

The slope

On positive elevation gains, the effort required of the horse is greater than on flat ground: he must overcome the gravity which tends to prevent his progress. The higher the elevation gain, the more intense the effort. The horse stride length decreases sharply due to the extra force required to cover the same distance as on the flat part of the track. Training horses on uphill slopes allows them to work on a large effort without reaching maximum speed. The horse develops his power and musculature.

ANALYSING STRIDE DATA TO PREVENT THE INJURY RISK

Analysing your horses' locomotion allows you to detect injuries or early signs of pathologies. By following the values of symmetry, regularity, stride frequency and stride length, you can carry out a **longitudinal follow-up** and complete the analysis of the heart rate.

Changes in the horse's gait can be a sign of suffering due to injury. For example, an increase in a horse's stride rate may be a sign of pain.

THE EXPERT OPINION

Dr Emmanuelle van Erck

Veterinarian Doctor, European specialist in internal equine medicine Equine Sports Medicine Practice, Belgium

Sports performance is no coincidence. It is the result of optimal physical preparation and excellent health. The technological revolution over the last 20 years has changed our approach to sport, regardless of the athletic discipline. Connected objects allows athletes and their trainers to objectively measure the body's response to physical effort, whether the athlete was doing too much or too little and to what extent training could be optimized, both to improve performance and to avoid injuries.

Arioneo has developed EQUIMETRE, a new system for measuring and monitoring the horse's physical performance. Unlike other connected devices, EQUIMETRE allows integration of many sporting parameters, while offering a simple understanding of the exercise. The trainer has, at his disposal, the ability to re-run trainings, the speed of the horse, and also, furlong by furlong, locomotion and heart rate. The quality of the measurements is such that they can be used to establish a diagnosis of cardiac arrhythmia based on the recorded electrocardiogram.

«EQUIMETRE from Arioneo has established itself as a partner in the health and performance of horses.»

The training strategy depends on the level of fitness and recovery after work and competition. EQUIMETRE makes it possible to evaluate recovery in the short and medium term, giving information on the horse's state of fatigue and his ability to progress.The measured parameters can be compared from one training session to another, from week to week. The trainer therefore has the means to concretely evaluate a horse's progress during training, to compare the individual horse to himself as well as to other horses on the yard. Thousands of measurements acquired with horses of different profiles have made it possible to understand how each horse responds differently to his training. Therefore allowing the difficulty of the work of each athlete, to be adapted according to each individual's capabilities. Thus, when a horse responds easily and quickly to work, the trainer can safely choose to intensify the exercise and optimize the horse's state of fitness.

True to its origins, EQUIMETRE is intended not only to be a training monitoring tool but also a tool in sports medicine, useful for monitoring the athlete's health. The measurements make it possible to establish if the horse has worked within the limits of its physical abilities. If his capacities have been exceeded, is it the result of a lack of quality or a possible weakness related to a health problem that has evolved slowly ? The concept is to allow the trainer to react immediately and prevent problems and injuries before they occur. In a horse that has a proven injury or disease, EQUIMETRE is used to accompany the revalidation period, to determine if recovery times and recovery procedures are working. This avoids returning to work too early and to step up training at the horse's own pace.EQUIMETRE from Arioneo has established itself as a partner in the health and performance of horses.

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