Biomechanics Manual

Functional Horse Training

Combining art with science to establish optimal movement

TABLE OF CONTENTS

FOREWORD

This manual aims to give you a compact overview and understanding of equine biomechanics, complementary to the video series in Module 2 Biomechanics of the online program.

This manual is the result of many years of research and personal experience world-wide. To bring about this manual, I have included comparative literature research of some of the most influential scientific works. However, caution to interpret this research is warranted. Biomechanics is not knowledge but rather a dynamic continuous study. Although certain mechanical laws apply to all horses, we always need to consider individuality and functionality for the horse. Studying biomechanics is not necessarily easy as we're dealing with nature. Hence, I'll try to make it as ''*simple as the complexity allows, but not simpler.*'' – Einstein

I sincerely hope that this complementary manual will be useful to your personal learning experience about equine biomechanics. It is my wish that some of this content might give you a deeper understanding of your equine partner and enables you to improve its quality of life.

COPYRIGHTS

Please take note that the content of this manual is copyrighted by Functional Horse Training Thirza Hendriks. It is strictly forbidden to change or publish this document online or distribute to third parties without the explicit written consent of Thirza Hendriks herself.

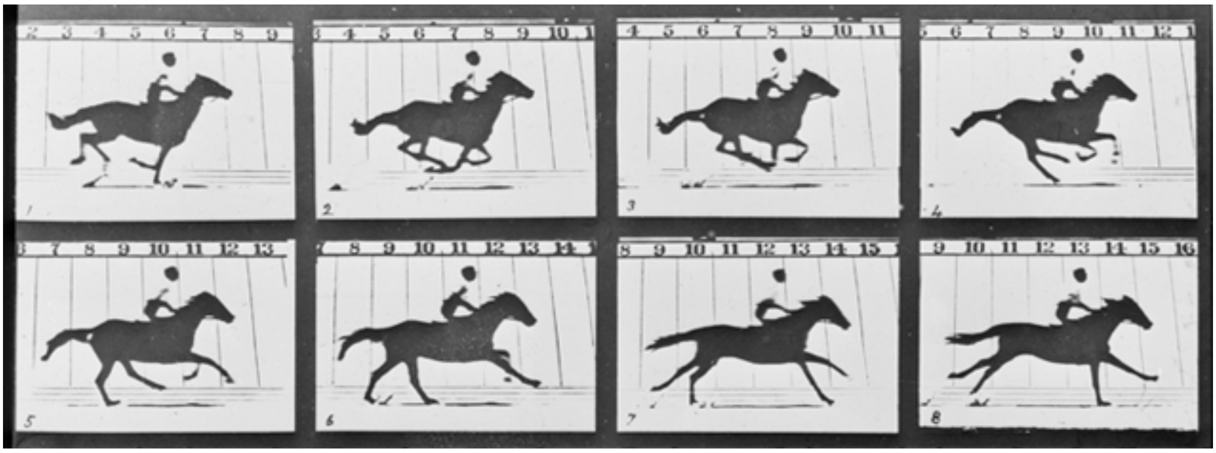
DISCLAIMER

This document has been compiled with great care to ensure the accuracy of the information. Thirza Hendriks cannot be held responsible for incorrect information in this document, or any damage caused by incorrect use of this information. This document does not replace veterinary diagnosis and no definite medical conclusions can be drawn from this document.

DEFINITION

Biomechanics is a popular term in the equine world. As per the official definition, *''the word "biomechanics" (1899) and the related "biomechanical" (1856) come from the Ancient Greek βίος bios "life" and μηχανική, mēchanikē "mechanics", to refer to the study of the mechanical principles of living organisms, particularly their movement and structure.'' - Wikipedia*

In short, biomechanics is the study of the mechanics of a living body that includes kinematics (motion) and kinetics (forces) (Fung 1993). It is an ongoing study and not knowledge. Understanding biomechanics will assist to accurately differentiate between what is normal or abnormal movement.



Fun fact: in 1878, Edward Muybridge was the first person in the world to produce a motion picture. His subject? A racehorse. His pioneering work advanced the study field of biomechanics exponentially as it enabled us to see slow motion frames of each stride phase.

Given the intricacies and variations of biomechanics between individual horses, a challenging task of shaping what constitutes normal movement arises. In modern day, this task is becoming more difficult to overcome given the level of cross- and inbreeding which is compounded with increasing research, training methods and theories as to what constitutes correct movement.

When selecting and breeding horses for fashion instead of function, the abnormal might become normal simply due to its prevalence. In other words, we might see so much abnormal movement that it biases our brain into believing that it is normal. Normalizing the abnormal is dangerous as it results in a loss of functional biomechanics at the disadvantage of the horse.

The way we look at horses is dictated by historical standards. Visual documentations of horses over time have been relied upon as the reference of what is normal.

Most notably throughout bombastic eras, such as the renaissance period, there are many depictions of horses that would now be considered to have typical conformational flaws and poor posture. If you walk around a historically rich city, chances are you will find a statue of horse and rider. Often, these statues show tension, incorrect movement, and poor posture.

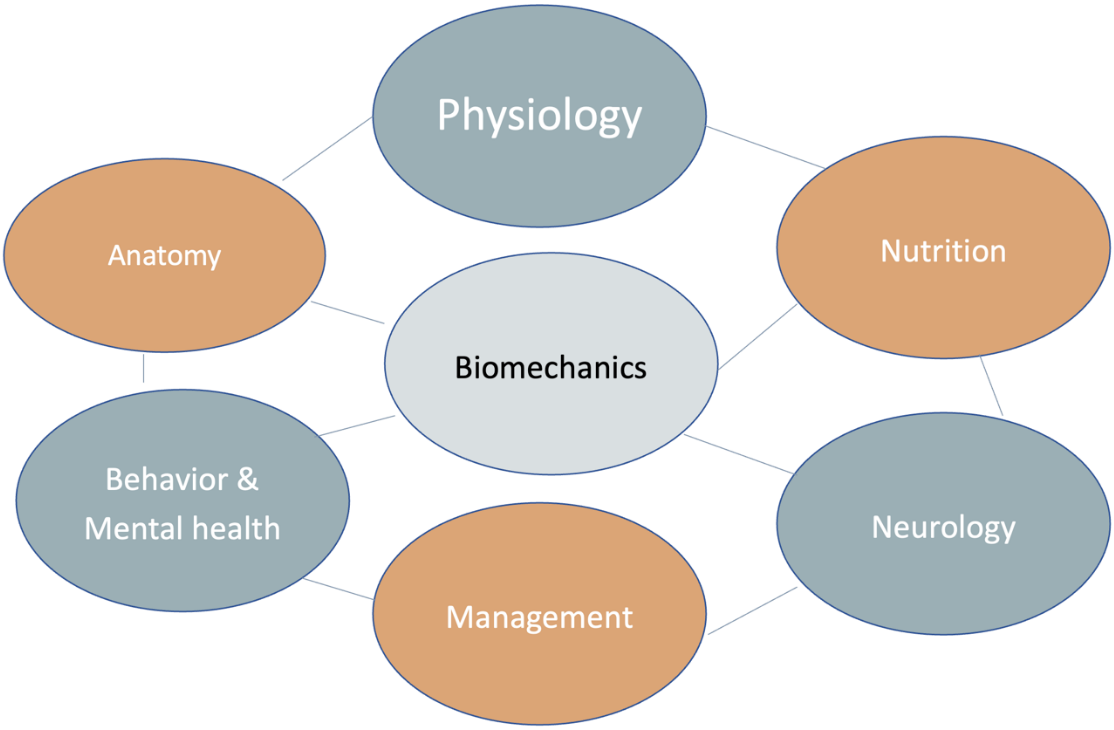
These artworks have hugely influenced the way we perceive the normal and over time, we seem to have become so accustomed to the abnormal that we have accepted it as a new standard without considering what we might lose in the process.

Apart from historical standards, the way we look at horses today is also heavily influenced by competition standards and results. Now that we no longer need them for our economies or to wage our wars, horses are mainly considered superb athletes and consciously selected to perform at top sport levels in various disciplines. The standards of the sport are subjected to change and shape what we find desirable in a horse resulting in fluctuating breeding practices. In other words, we don't want the same type of horse we wanted 30 years ago, and the breeders adapt the supply to the changing demand of the market. Unfortunately, fashion is always temporarily, but function is not.

Throughout history we have always taken from the horse. Horses has served us for thousands of years and now it is time to give something back to them. With the advantage of modern-day science, we can study functional biomechanics and help to raise awareness about what is normal vs what is abnormal to improve horse welfare around the world.

BIOMECHANICAL MODELS

Biomechanical models are aimed to explain how the body is designed for



motion and how it accomplishes that motion. The production of movement requires close integration of various body systems, making it highly complex and multi-layered.

Biomechanical models are simplifications of a complex reality to help us understand. Although simplifications are the greatest achievement of knowledge, simplifications without knowledge are the greatest cause of equine injuries (Cornille 2012). In other words, preaching concepts such as ''ride your horse over the back'' or ''engage the hind limbs'' are empty without proper mechanical understanding and often lead to incorrect practices. It is thus crucial to study the horse's biomechanics to reduce the risk of overload and injuries.

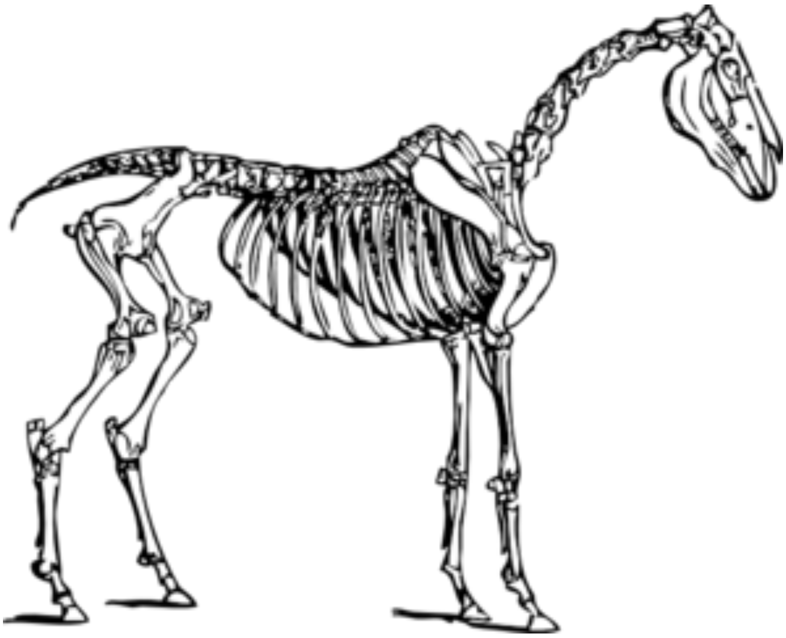
The one constant force that influences biomechanics is gravity. Pregnancy, excess weight, tack, and a rider increase the mass that gravity acts on. Hence, the horse's body needs to be equipped with refined mechanical systems that allow it to move while resisting gravity.

Equine biomechanics is often explained from a comparative human perspective. However, despite some similarities, humans and horses are very different in their anatomical design. Humans are two-legged and built in the vertical plane whereas horses are four-legged and built in the horizontal plane.

Due to their vertical build, humans have an advantage when it comes to defying gravity since two vertical forces in opposite directions can relatively easily annual each other out. Horses, however, draw the short end of the straw; being built horizontal, it is much harder to defy gravity. The horse is thus not a human and has to rely on different sophisticated mechanical systems to maintain balance against gravity. So, what do we know about equine biomechanics?

When looking at the horse's anatomy, we can observe differences in anatomical design of the front limbs and hind limbs. The hind limbs are angular, like that of a cat, and allow for bending. As such, their main task is to produce horizontal forces (forward movement). In certain situations, the hind limbs are also tasked to produce breaking forces to keep the bodyweight balanced between the fore- and the hindlimbs.

When looking at the design of the forelimbs, they are much more upright like a rigid strut. Hence, their main task is to produce a vertical incline against gravity. Balance control is thus essentially in the horse's forehand – not in the hind end.



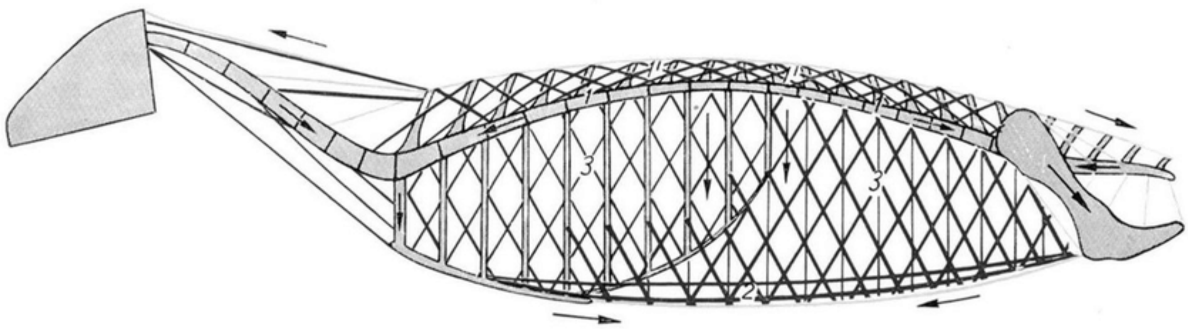
Picture showing the differences in anatomical design between the hind- and front limbs

From a neurological perspective, there are more nerves governing the forehand than the hind end, demonstrating that the front limbs tend to predominate over the action of the hind limbs. This is the result of the action of two neural oscillators referred to as central pattern generators. These central pattern generators maintain the purity of the gaits and cause the hindlegs to follow similar patterns of movement as the forelimbs. The front central pattern generator is thus the decision maker as it informs the hind end, which provides feedback. There is some feedback from hind end to front end but the main message regarding the gait itself is coming from the front central pattern generator (McLean, 2021).

In essence, equine biomechanics is about producing horizontal forces (forward movement) and converting these forces into a vertical incline against gravity to ensure balance control and maintaining spinal integrity.

The hind- and front limbs are connected through the pelvic articulations and thoracolumbar spine. The thoracolumbar spine is the main horizontal component in the horse's anatomical design and thus heavily burdened by gravity. Maintaining spinal stability and integrity is essential to ensure sound biomechanics against gravity.

To understand the interactions between the vertebral column and limbs, various efforts have been made to develop a crude biomechanical model. To date, there is only one widely accepted model available that continues to shape our thinking and training practices, namely the infamous string-and-bow theory.



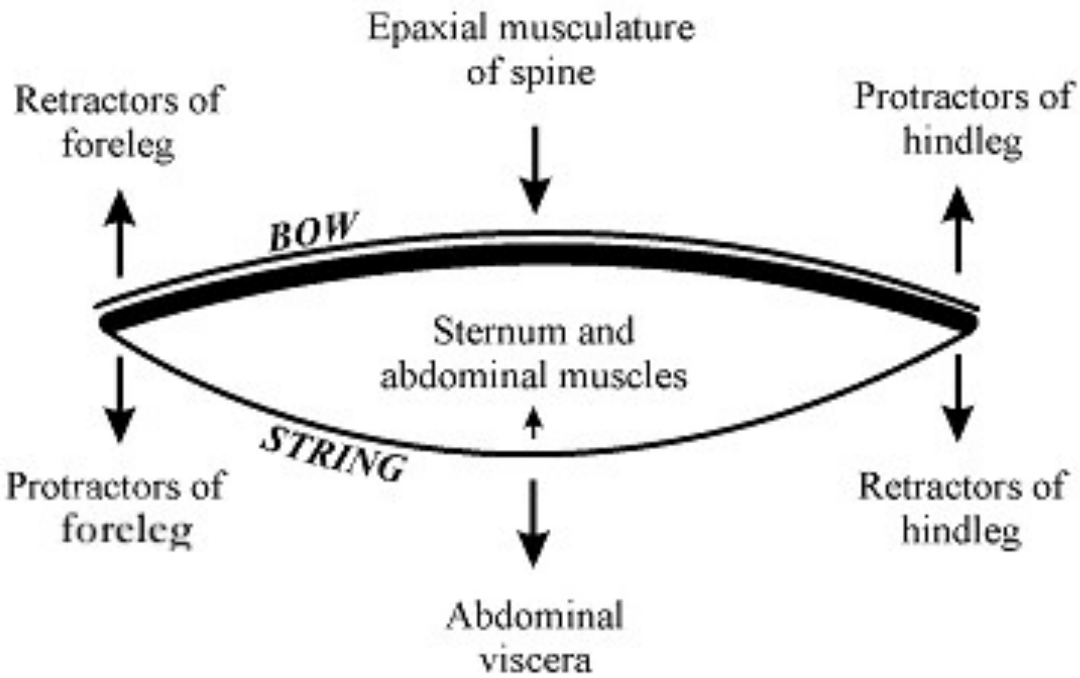
The idea of the trunk-skeleton connection as a bow and string construction was first proposed by Barthez in 1798, but his work was ignored until rediscovered by Dutch scientist Slijper in 1946, who described it as follows:

"The horse has a very flat shaped bow which is made up of the vertebral column, its epaxial muscles and ligaments. The whole structure is kept rigid and under tension from the string formed by the sternum, abdominal muscles, Linea alba and the muscles of the limbs." - E. J. Slijper, 1946

The bow and string are connected through the ribs, the oblique and transverse abdominal muscles.

For the string-and-bow theory to work, it relies on two additional influences:

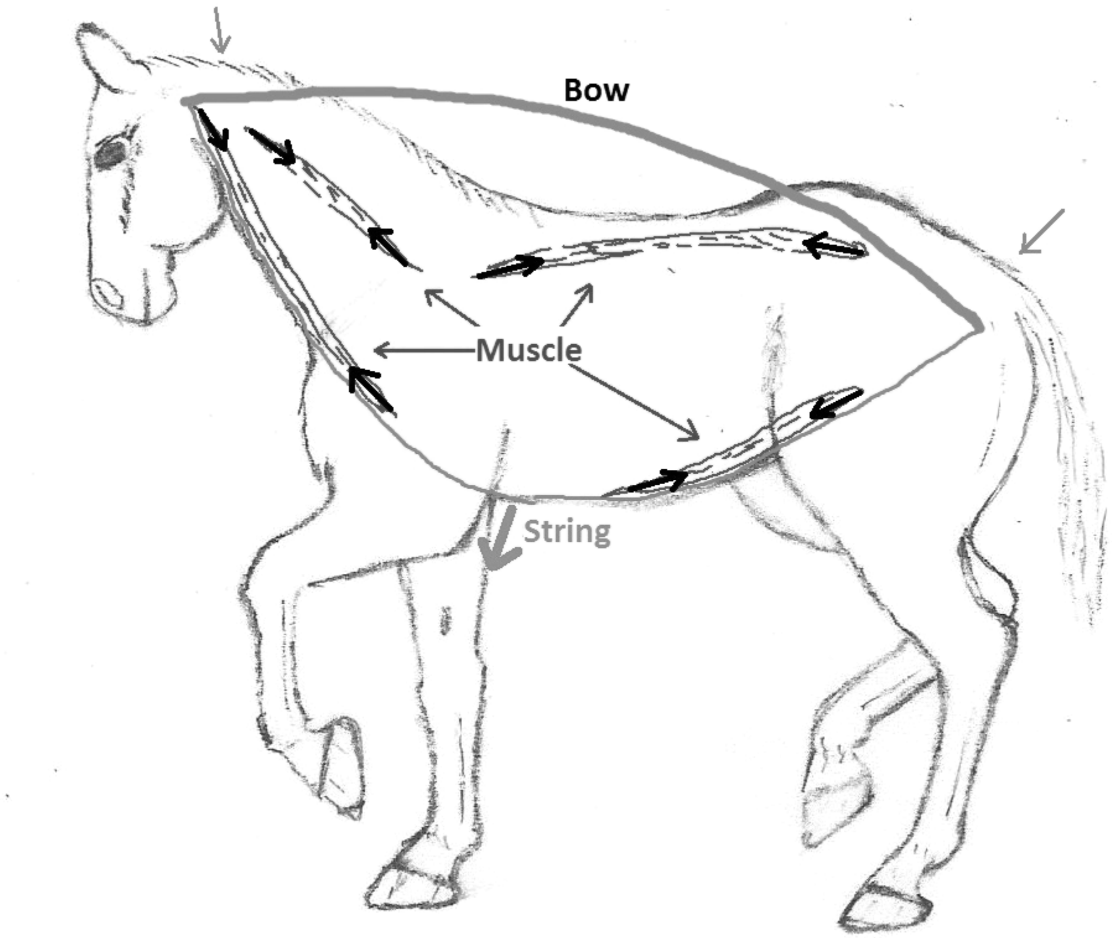
- The head and neck position
- The engagement of the hind limbs



Simply put, the string-and-bow theory teaches that by engaging the horse's hindlimbs and lowering and flexing the head and neck position, the horse's back flexes through activation of the abdominal muscles allowing the horse to balance against gravity and carry a rider with minimal wear and tear.

After its initial publication, Slijper's crude model became widely accepted. Today, the string-and-bow theory is of biblical proportions in equitation. It has been responsible for training dogma's such as long and low, low deep and round, rollkür, core stability for horses and hind limb engagement. Sounds familiar right?

The string-and-bow has become part of equitation tradition without room for critical thinkers. Questions on the validity already arose in the 1960s, by scientists such as Ricard Tucker, Leo Jeffcott and James Rooney, but were met with resistance by the equestrian elite. Research disproving the string and bow theory continued in the early 2000s, but its outcomes seem to have fallen on deaf ears. It appears that in the equestrian world, tradition is often favored over science and the myth of the string-and-bow continues.

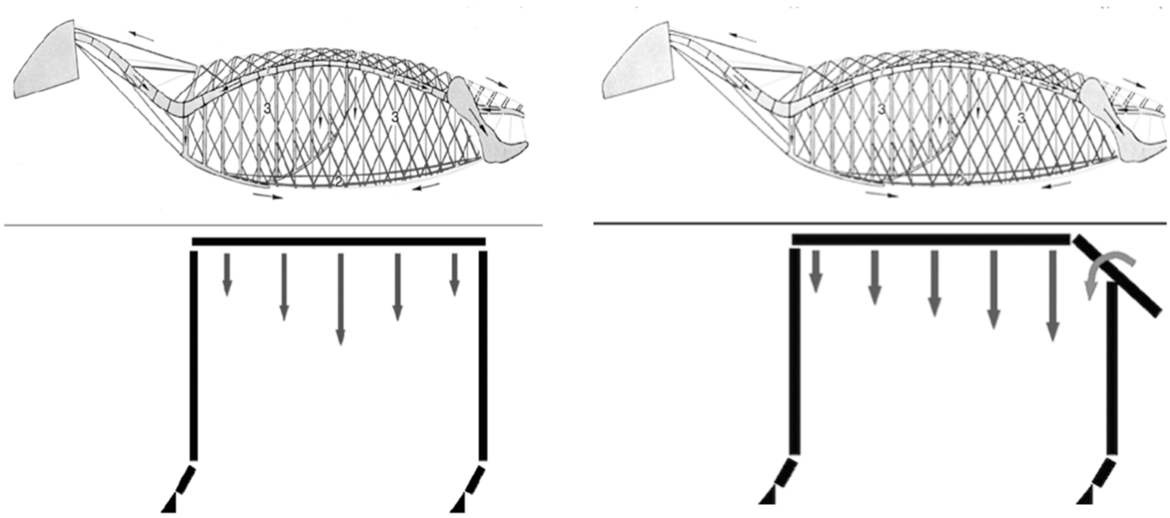


To give the model some credit, it was one of the first models that allowed for the fact that the back is in dynamic balance under constantly changing tension. A force on one part, alters the biomechanics of the other parts. However, modern day science has helped us to evolve our understanding of this complex topic. There are three main reasons why the string-and-bow theory in its current shape is flawed and should be revised:

1. The role of the lumbo-sacral joint
2. Redefining the ''core'' muscles
3. The negative effect of long and low

1. The bow and string theory does not help with analyzing the pelvis or the interaction between sacro-lumbar spine, pelvis, and hind limbs.

The string and bow theory surmises that peak forces of flexion and extension occur mid-back (the center of the bow). However, science has shown that peak forces of flexion – extension occur at the lumbo-sacral joint, which acts like a hinge and greatly contributes to the horse's athletic capacity due its loin-coiling ability.



Picture adapted from Van Weeren (2016) showing the string-and-bow theory (1) not accounting for pelvic articulations and (2) an adaptation accounting for flexion/extension of the lumbosacral joint.

The lumbo-sacral joint is part of the sacral-pelvic sling and in turn is greatly influenced by the hind limb's rotation around the hip joints. Biomechanics of the sacro-pelvic sling are thus crucial for whole body movement.

Since peak forces do not arise mid-back, the entire concept of a ''rounded'' or ''lifted'' back should reconsidered. Rather than the back arching like a bow, it is more a case of the sacrum lowering, the thoracic sling lifting while keeping the back as straight as possible against gravity.

2. Within the string-and-bow theory, the abdominal muscles of the horse are considered the ''core'' muscles responsible for flexing the thoracolumbar spine and this has led to an overflow of ''core stability'' training programs for horses. However, the abdominal muscles of the horse function differently to common belief and are not responsible for creating flexion in the spine.

The main task of the abdominal muscles in the horse is to assist the breathing process. As already explained in the anatomy manual, the breathing process of the horse is more active than that of humans and requires more engagement of the abdominal muscles to support the diaphragm. A strong abdominal line, especially that of the external oblique is rather a sign of breathing difficulties as opposed to the horse having a strong ''sixpack''.

On a mechanical level, the abdominal muscles have two functions. Firstly, they stabilize the visceral content in the higher gaits. Secondly, various ECG studies (Tokuriki, 1997; Von Scheven, 2010) found that the abdominal muscles are active during the extension phase and not the flexion phase of movement. This is completely contradictory to what the string-and-bow theory makes us believe.

We often think of the back as something that should move, but it should also limit movement to remain straight and resist gravity. As such, the abdominal muscles engage in an antagonistic relationship to the long back muscles, such as the Longissimus Dorsi to maintain tensegrity.

With gravity acting downwards, the Longissimus Dorsi and External Oblique act in a harmonious concert to keep the spine within its integrity. Instead of creating flexion, the External Oblique activates to limit (excessive) extension. The opposite is true for the Longissimus Dorsi that instead of creating extension, acts to limit flexion. This phenomenon can be clinically observed as well. When a horse presents with a strong muscle line of abdominal oblique under the rider, have a look to the posture of the lumbar spine: 99% of the times it is in extension. If the horse is trained in a contracted posture, the lower back is succumbing to gravity and the increased mass it is acting on.

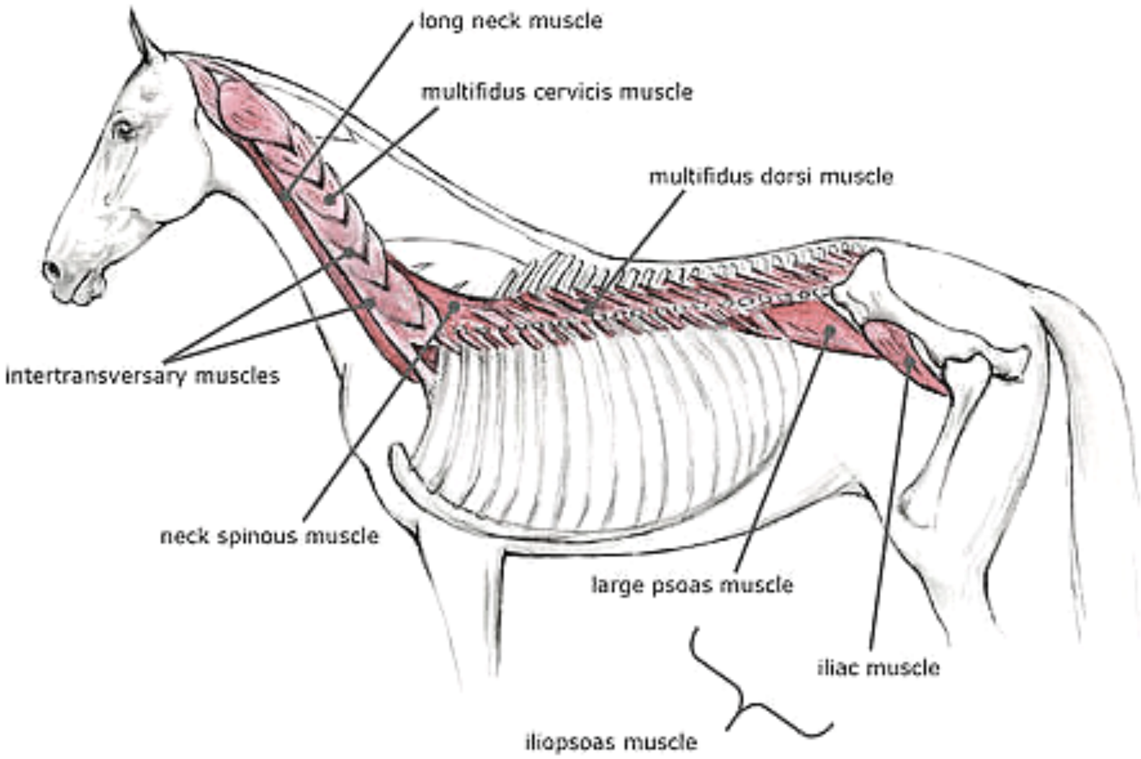
As a result, the external oblique will create heavily, not to create flexion, but to limit the extension to keep the back stabilized and straight as much as possible against gravity and the rider.

Picture showing an extended lumbar spine in combination with a clear muscle lining of the External Oblique

The question is, if not the abdominal muscles, what muscles are mainly responsible of back tensegrity instead? The answer lies in the cybernetic stabilizers.

As explained in Module 1. Anatomy, the cybernetic stabilizers are highly innervated postural muscles closely connected to the vertebral column.

These are the deepest layers of muscles and thus are the true ''core muscles'' of the horse. These true core muscles of the horse include the Quadratus Lumborum, Multifidi, Intertransversarii, Longus Coli, Scalenus and Iliopsoas.



These previously overlooked postural core muscles are major players in spinal stability and there extremely important to ensure correct biomechanics as horses require a stable spinal platform from which to execute voluntary movement. Spinal stability is necessary to respond to destabilizing forces such as gravity and a rider and reduce the horse’s chance of injury.

A recent study that aimed to explain the relationship between the Multifidus muscle and chronic lameness found that horses with a unilateral forelimb lameness showed bilateral atrophy of the Multifidus causing a lack of spinal stability in these horses (Sullivan et al. 2022).

The importance of the postural muscles become increasingly clear and should therefore gain more attention in biomechanical models.

This is not to say the abdominal muscles have no function at all, but that they merely complement biomechanics rather than creating it. Flawed understanding of the function of the abdominals lead to one-sighted approaches that completely bypass the true core muscles that ensure posture and sound locomotion.

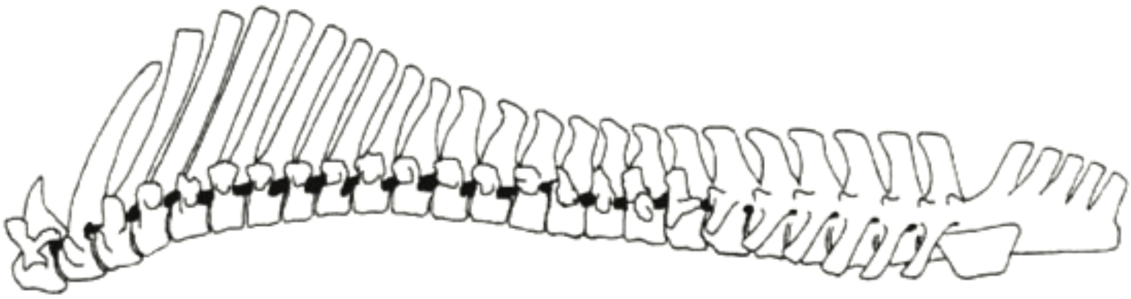
Core training for horses based on abdominal contraction (only) is thus flawed simply because it doesn't address the actual core muscles, the deep postural stabilizers surrounding the spine itself. Therefore, the string-and-bow theory needs to be revised as it has been responsible for many misinformed training practices not benefiting the horse.

3. Finally, for the string-and-bow theory to work, it relies on two additional influences, namely a lowered head and neck position and the engagement of the hind limbs. However, the two concepts are incompatible with one another since a long and low(er) head and neck position naturally disengages the hind limbs through extension in the lumbo-sacral joint.

The string-and-bow theory compares the spine to a homogenous bow. However, in reality, different design and orientation of vertebrae allow for different range of motion. This means that a single action (such as lowering the head and neck position) causes different reactions throughout segments of the thoracolumbar spine.

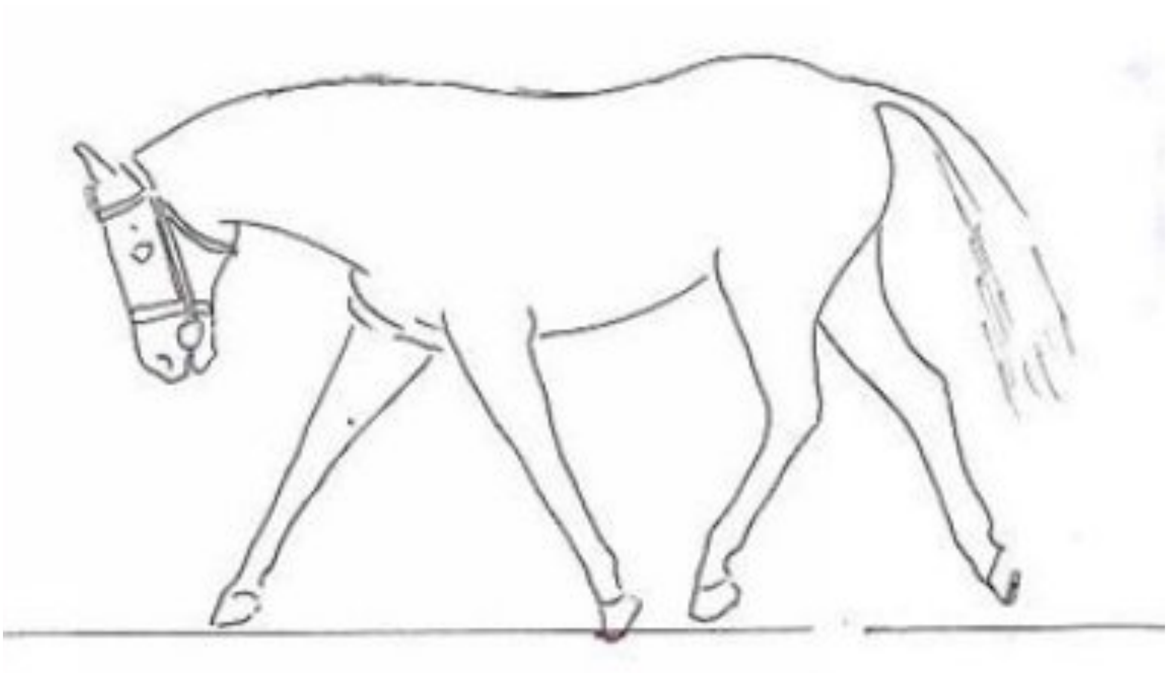
When looking at the orientation and design of the thoracolumbar vertebrae, there is somewhat of a curve. The dorsal spinous processes of the first thoracic vertebrae are long and orientate slightly backwards (caudal). Gradually continuing mid-back, the spinous processes become shorter and orientate more upright. Progressing through the lumbar spine, the dorsal spinous

processes change angle again and orientate forwards (cranial). The thoracolumbar spine has thus an evident curve that changes from a caudal to a cranial orientation of the dorsal spinous processes.
These processes are influenced by muscle and ligament attachments – for example the Supraspinous ligament.



Picture showing the curvature in the spine. A single action of the head and neck forwards-downwards will result in flexion in the thoracic spine, but extension at the lumbar spine.

When the horse is asked towards a lower and/or rounder head and neck position, qualified as any position with the ears at least a hand lower than the withers and croup, the Supraspinous ligament pulls in the same direction as the head and neck. However, the effect won't be same over the entire length of the thoracolumbar spine. In the thoracic vertebrae, the pull direction will straighten the backwards orienting processes more upright through muscular and Supraspinous ligament actions creating flexion. However, in the lumbar spine, the exact same forward pull direction will tip the naturally forward orientating processes even more forward, resulting in extension. As a result, the sacro-pelvic angle flattens, and the pelvis wants to ''tip over''. In reaction to the extension of the lumbar spine and increased load on the forehand, the hind limbs will increase their extension (thrust) rather than their flexion (carrying) phase. As such, a long and low head and neck position and engagement of the hind limbs are two incompatible concepts.

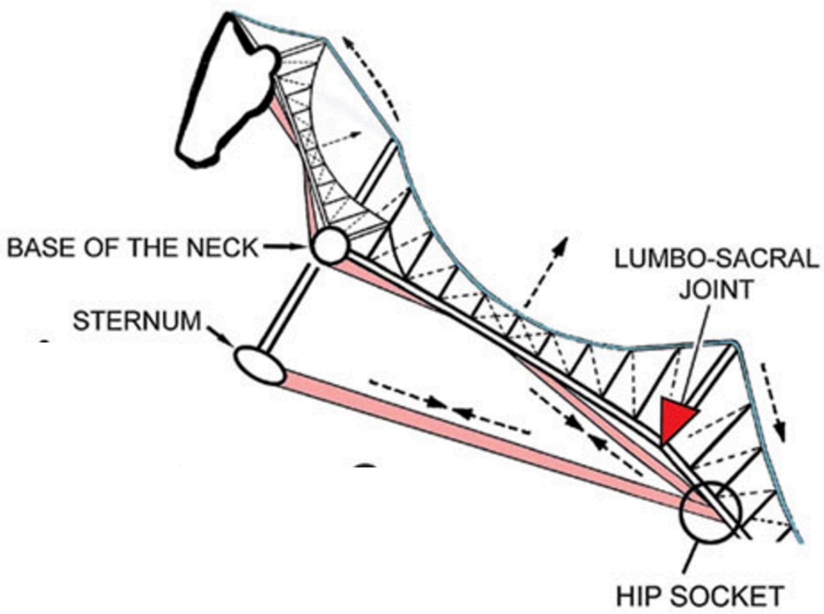


Picture adapted from Cornille (2012) showing the ''wheelbarrow'' effect of long and low and how it is incompatible with the concept of hind limb engagement.

All the above-mentioned reasons clearly debunk the string-and-bow theory and demands it to evolve using modern day science. Biomechanics is far more complex and sophisticated than what the string-and-bow theory accounts for and this can lead to flawed training practices. It is necessary to break down tradition to build up a more accurate biomechanical model that serves justice to the horse and include more sophisticated intricacies.

Going back to the drawing board using current scientific knowledge and experience, a more accurate biomechanical model can be realized including the close integration of the following mechanisms:

1. Rotation about the hip joint (sacro-pelvic sling)
2. Flexion – Extension of the lumbo-sacral joint (sacro-pelvic sling)
3. Postural vertebral integrity (core muscles)
4. Thoracic sling engagement
5. Abdominal support
6. Elastic strain energy of tendons



Picture displaying a more accurate biomechanical model. All the intricacies of this model will be explained extensively in Module 2. Advanced Biomechanics.

Simplified, this model states that biomechanics starts with force production from the hind limbs that is realized through rotation of the hip joint (1) and flexion – extension of the lumbar sacral joint (2). These forces are then transmitted through the back, which absorbs and redirects these forces through postural support from the core stabilizer muscles (3). Once the forces end up at the forehand, it must be converted into a vertical incline against gravity through engagement of the thoracic sling (4). The action of biomechanics is then concluded through abdominal support (5).

Finally, efficiency of movement (6) to reduce muscular effort is realized through elastic strain energy of tendons which ensure that motion is both balanced as well as light, allowing the horse to move with optimal efficiency, but minimal effort.

Due to the complexity of this model, Module 2. Advanced Biomechanics explains each of these mechanisms in depth, dealing with both mechanics as well as equine energetics.

BIOMECHANICAL ASSESSMENT

A biomechanical assessment is a structured process aimed to collect information with regards to the functionality, load capacity and trainability of the horse.

Learning outcomes include:

- To be able to recognizes conformational and postural imbalances
- To be able to select form to function with regards to performance
- To identify gait abnormalities and biomechanical dysfunctions
- To be able to assess the horse on a more complete level
- To be able to recognize stress, pain, and discomfort

When performing an assessment, it is important to consider the following factors:

- Don't assume the problem before you see the horse
- Keep an open mind and don't jump too quick to conclusions
- Don't overthink and try to put all the pieces together in a first assessment.

- Assess only and never undertake a diagnostic approach as this contravenes the veterinary act. An assessment does not replace veterinary diagnosis and no definite medical conclusions can be drawn from the results thereof.

Basic structure

To keep oversight, each assessment should follow a logical structure:

1. General information
2. Observation (static)
3. First Palpation
4. Observation (dynamic)
5. Second palpation

Assessment tools

Assessment skills guide you to make educated decisions. Basic assessment tools include:

- Sight – to observe the entire body
- Hearing – to hear the footfalls and internal noises
- Touch – to gather bodily information through your hands
- Smell – to detect possible infections
- 6th sense – To employ your gut-feeling /
- Physical tools – for example a hoof tester

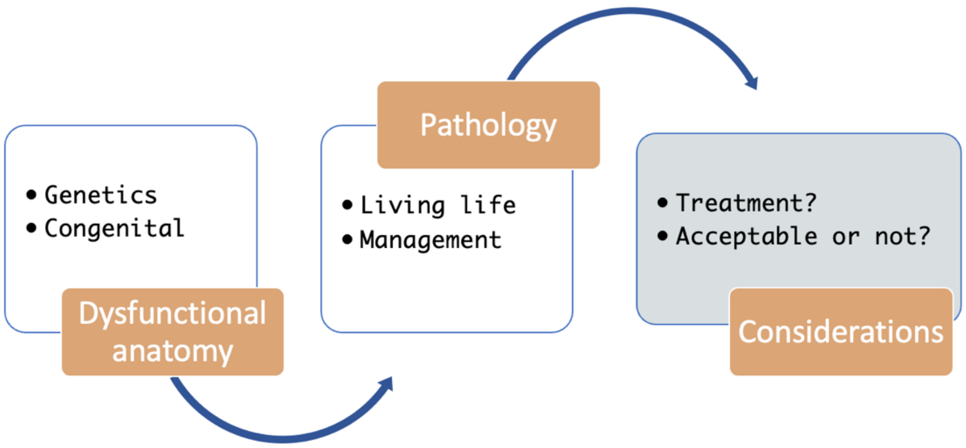
Overall markers

During the entire assessment, you check the presence / absence of the following makers:

- Pain / Stress / Discomfort signals
- Abnormal posture
- Altered gaits
- Soft tissue development
- Stiffness / reduced mobility

Assessments outcomes

Simply put, there are two possible outcomes of every assessment: biomechanics is either normal or abnormal. When biomechanics appears to be abnormal there can be various causes and consequences:



Always consider your assessment outcomes in relation to confirmation versus posture. Just like all creatures great and small, horses come in many different, shapes, sizes, and colors. Some of these variations can be categorized by breed. Horse breeds vary according to where they originated, and characteristics have been altered by humans deliberately breeding dominant genes to enhance or achieve a desired trait (Rogers 2010). Over time, each breed has been developed according to a standard of excellence for 'type' that includes correct conformation representing the requirement of the breed to perform specific tasks. These standards are of course ideal and, there can be broad individual variations, even among horses of the same breeds. Confirmation is usually the most important factor of interest to breeders or judges at tests. Certain traits such as roach back or sway back are considered conformational faults. The question is, are these traits confirmation or can there be underlying influences – such as postural issues - causing these appearances.

To clarify the terms, confirmation describes characteristics derived from breeding such as hair color, length, and size of skeletal structure. Confirmation should always be assessed in relation to function. A horse with less-than-ideal confirmation for jumping could have excellent confirmation for dressage and there are many horses that excel in any chosen discipline without having perfect conformation.

Posture on the other hand describes how the horse organizes itself in the way it stands and moves. The ability to differentiate between confirmation and posture can be crucial as posture can be improved whereas confirmation cannot.

Many traits assigned to poor confirmation are in fact due to poor posture. This opens up a range of new possibilities as with knowledge and experience, you can take the action needed to bring your horse's body and mind back into balance. *''This may not only improve the appearance of its confirmation, but also make a significant difference to its performance ability, comfort, and long-term health.''* - Rogers 2010

Closely observing and palpating your horse on a regular basis will reveal information that you need to determine the difference between confirmation and posture with the general rule that if something appears to be present from birth, it is conformational, as to whether it occurred during life, it should be considered postural, which can often be improved with proper management adaptions to ensure the best life possible for the horse.

The coming chapters will explore each component of a biomechanical assessment more in depth.

General background information

To set yourself up for success, always start with collecting a much background information as possible:

- Age
- Breed
- Discipline/Training
- Medical history
- Management routine

Age can play a factor in assessing for lameness. In general, foals are more likely to have infection causes of lameness. A young horse starting training may be lame due to a developmental orthopedic disease such as OCD. Older horses are more likely to experience arthritis.

Certain issues, especially genetic disorders, are more prevalent in certain **breeds**.

Another factor to consider is **discipline and general training schedule**. Certain lameness's and bodily issues are associated with specific uses. See the diagram on the next page for a general outline.

The **medical history** of a horse should also be considered. An old injury may re-occur over time depending on the nature and location thereof. Additionally, the horse might also show bodily issues due to long time compensation for a past injury. In the case of a progressive disease, such as osteoarthritis, a horse will often experience recurrent lameness that must be managed. Shifting lameness may suggest a bilateral injury or infectious cause of lameness.

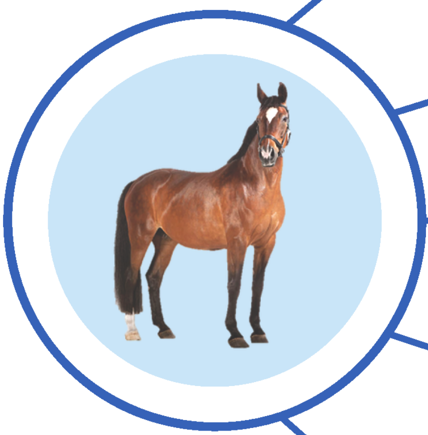
DISPLINE	CONDITIONS
Dressage	Vertebral column & pelvic issues, hip/hock/stifle, fetlock changes, bone and bog spavin, neck & lumbar arthritis.
Reining	Hamstring tears, Fibrotic myopathy, SI strain, early hock arthritis, bone & bog spavin, curb, and fracture of the 2^{nd} phalanx in the hind.
Endurance	Bowed tendons, pedal osteitis, hoof and leg injuries, bruised soles, back pain, and fatigue/stress fractures.
Racing	Bucked shins: fatigue/ stress fractures, bowed tendons, carpitis, carpal chips and slab fractures, fetlock arthritis and chip fractures, sesamoid changes and fractures, subluxation of SI joint, stifle strain, vertebral changes.
Jumping	Navicular syndrome, bowed tendons, ligament sprains, SI strain, back pain, vertebral changes muscle fatigue.

Finally, the **management routine** of the horse should be considered. Recent changes in training, turnout, exercise, diet and/or trimming/shoeing are known factors that affect biomechanics.

General health

Measure the horse's vitals to get an understanding of its general health.

EQUINE VITAL SIGNS



1 TEMPERATURE
Normal: 99.0 - 101.5 F
Abnormal: greater than 102 F

2 HEART RATE
Normal: 28 - 42 beats/minute
Abnormal: greater than 48 beats/minute

3 RESPIRATION
Normal: 8 -16 breaths/minute
Abnormal: greater than 20

4 CAPILLARY REFILL TIME
Normal: Less than 2 seconds
Abnormal: Greater than 3 seconds

5 MUCUS MEMBRANES
Normal: Pink (Bubble gum color)
Abnormal: White, Red or Blue (Purple)

Observation

The observation phase in standstill is a visual whole-body scan that closely monitors facial expressions and reactions of the horse as well.

When observing a horse, stand back a few meters and observe from the front, back and then both sides. In addition, it can also be useful to stand on a heightened surface such as a mounting block.
Ideally the horse stands square, but don't force this. If the horse is unable to stand square easily, consider this as valuable information complementing your assessment.

The following aspects can be observed:

- Mental state and first impression
- Confirmation, posture, and type
- Muscular hyper- and atrophy
- Abnormal swellings or blemishes
- General health issues
- (A)symmetry
- Limb deviations

Palpation

Palpation consists of collecting information with your hands and allows you to feel the texture, size, consistency, connection, and location of certain body parts.

Palpation will enable you to discern the following within the body:

- Respiration and heart rate
- Temperature (differences)
- Bony landmarks (symmetry)
- Tissue variations, tensions, symmetry & development
- Soft tissue strain, scars, tears, and calcifications
- Trigger points and muscle spams

Trigger points cause pain; they are a taut band of contracture within a limited number of muscle fibers, not involving the entire muscle. They may be a primary source of discomfort or secondary to dysfunction elsewhere. They often accompany other medical musculoskeletal conditions i.e., hip arthritis and can also accompany visceral problems i.e., gut issues.

A trigger point is defined as a ''*hyperirritable spot in a taut band of a skeletal muscle, which is painful on compression, stretch, overload, or contraction of the muscle and usually has a distinct referred pain pattern*'' – De Las Peñas 2014. Trigger pints can be latent or active. Active trigger points can create local and referred pain. Latent trigger points don't cause pain but can cause motor dysfunction e.g., weakness, increased muscle irritability, cramps. Trigger points may develop due to factors such as muscle overuse, overload, and repetitive minor trauma to an area, psychological stress and disorder affecting the viscera.

Muscle spasms are likely often a trigger point or become a trigger point when not addressed in the acute stage. Muscle spasms can become calcified the longer they are left unaddressed. They will disturb the function of the muscle involved and therefore the biomechanics and may then lead to more substantial injuries i.e., muscle tears or fractures.

The horse in movement

The horse is built for movement and therefore movement should serve the horse in its daily life. When biomechanics function properly, then locomotion is sound, easy, functional, efficient and has postural integrity.

Assessing locomotion involves:

- Physiological system functioning
- Mechanical system functioning
- Gait analysis

Physiological system functioning is about equine energetics and the physiological contributions to movement such as the respiratory- and cardiovascular system. Module 2. Advanced Biomechanics and Module 5. Exercise Physiology will dive deeper into the physiological side of movement.

Mechanical system functioning is about tensegrity within the body and allows the horse to move with optimal weight distribution and efficiency. Module 2. Advanced Biomechanics dives deeper into assessing the sling- and recoil systems.

Gait analysis is about observing the technical and functional quality of movement. It allows you to detect what is normal or abnormal movement in the horse. The course of the limb is primarily determined by:

- Hoof balance
- Alignment of the leg
- The ability of the leg to articulate smoothly
- Tendons, ligaments, fascia, and muscle groups involved in locomotion

Stride phases

In most gaits, each stride consists of several phases:

- **Stance phase** → when a foot is in contact with the ground.

- **Swing phase** → when a lifted hoof is brought forward in a pendulum action.

- **Suspension phase** → when no hooves are in contact with the ground.
  The walk is the only gait without suspension.

The stance phase can be further divided into four distinct stages:

- First impact (shock absorption)
- Second impact (shock absorption)
- Midstance (full weight bearing & support)
- Breakover (pushing the horse's body forward

Loading of the limbs during the stance phase occurs in two stages. Firstly the 'impact phase', which occurs immediately after the hoof contacts the ground and causes a rapid deacceleration in hoof speed which gives rise to a shock wave that travels proximally through the bones and joints.

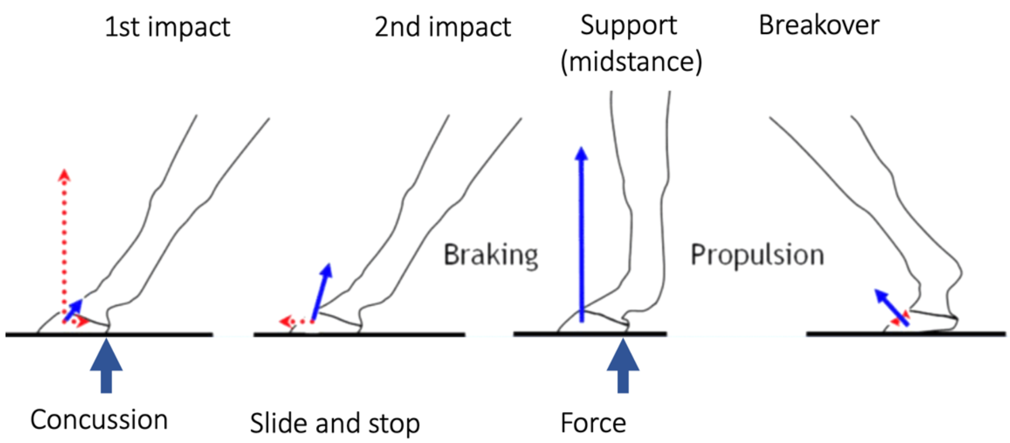


Diagram adapted from Peterson et al. (2012) showing the differences of each phase in acceleration and ground reaction force. When the blue arrow is tilted, it indicates that both vertical and horizontal components of the ground reaction force are present. The blue arrow shows the direction in which the ground is pushing the horse.

After the initial contact point and through the remainder of the stance phase, the limb is loaded more gradually until the limb pushes off against the ground to transition into the swing phase. The breakover is the moment when the hoof starts to tip forward and rotate over the toe to lose contact with the ground, thus signaling the beginning of the transition between the stance phase and swing phase. The breakover is initiated by rotation of the coffin bone through tension of the deep digital flexor and pressure in the navicular bursa and bone. The breakover is heavily influenced by hoof balance.

Picture showing biomechanics of the stride phases from stance to breakover

On a firm surface the hoof will stay on the ground until the heel comes off. On a softer surface there will be toe rotation in the surface before the heel comes off. This toe rotation reduces tension on the soft tissues within the foot, such as, the Deep Digital Flexor Tendon and navicular ligament (Butler 2017).

In general, hard tissues such as bone and joints are more prone to injury during the impact phase whereas, soft tissues are more likely to sustain injury during the loading phase.

Lameness is usually most evident during the support phase when the limb becomes fully load bearing.

The swing phase consists of the forward and upward movement of the limb and is influenced by the confirmation, alignment and movement of the horse's shoulder as well as thoracic sling development:

''With regard to conformation, a sloping shoulder facilitates forward and upward movement of the limb during the swing phase, so conformation of the shoulder may play a role in gait quality.'' - Holmström et al., 1990

The swing phase involves joint flexion and extension. During retraction, there is maximum flexion mid swing, followed by maximal joint extension in the protraction phase to prepare for landing.

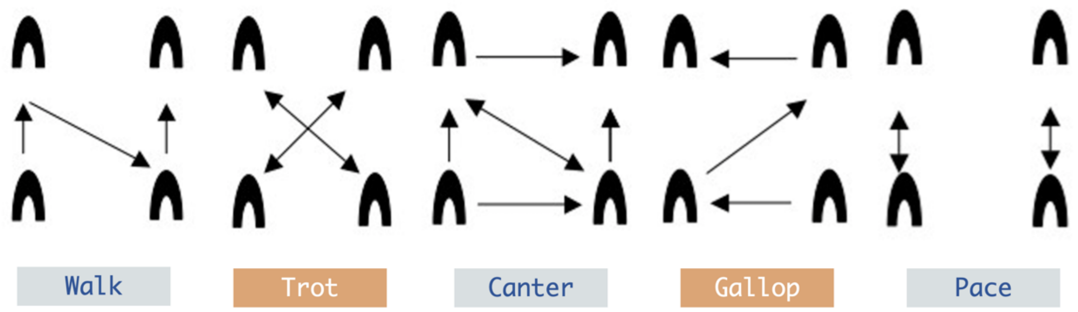
Abnormalities in the swing phase of the stride will lead to an off-center breakover which is often associated with upper limb biomechanical abnormalities. i.e., lateral break over of the hind foot with stifle issues. The hoof should land heel first as a toe first landing will decrease shock absorption and circulation in the hoof which leads to a weak caudal heel.

When assessing the quality of a horse's movement, professionals tend to focus on the swing phase, since this is when the expressiveness of the horse's movement is most apparent. However, expressiveness does not equal correctness and could result in certain issues being overlooked.

Furthermore, when identifying the cause of lameness, the swing phase is inferior for identification as the forces associated with this phase of the stride are modest. It is during the stance phase that large forces are applied to the musculoskeletal system, so evaluation of the stance phase is usually more informative in relation to performance-limiting factors or lameness (Clayton).

The suspension phase is when all limbs are off the ground. Suspension is naturally present in the trot and canter but absent in the walk.

NATURAL GAITS

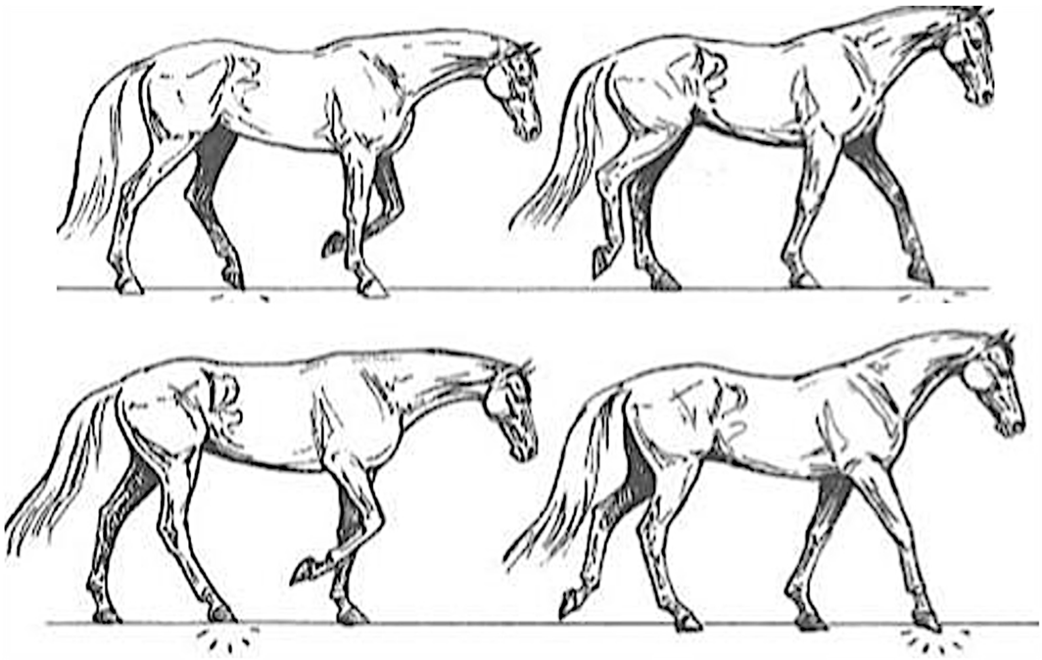


Most horses have four natural gaits, namely: walk, trot, canter, and gallop. Certain gaited breeds, have the natural ability for an extra gait such as ‘pace’ and ‘tölt.’ Although an ambling gait is a hereditary trait for such horse breeds, some of these horses may not always gait.

Walk

The walk is an asymmetrical four-beat gait with a lateral footfall and no aerial phase. It has both a bipedal and tripedal support phase. As speed increases, tripedal support decreases while bipedal support increases.

The ideal walk should have a rhythmical action which include evenly spaced strides and equally paced limb movements. As this gait is where most back movement occurs, the horse should move with a functional back and barrel, a figure of eight motion in the pelvis and a loose tail. The head should display a small – J shaped, lateral movement at a working pace, but will become more vertical in action when the walk is sped up or lengthened.



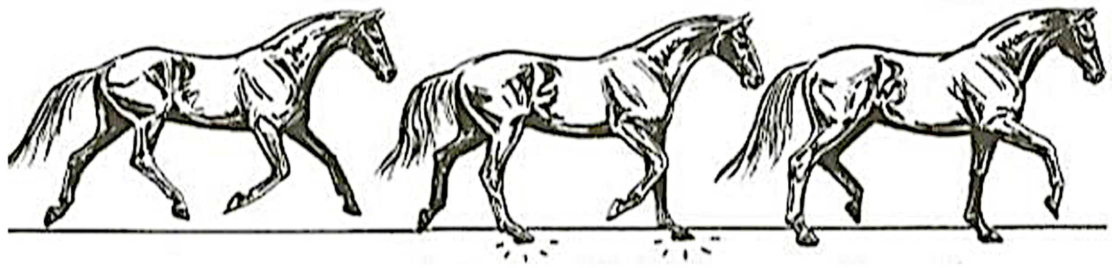
A common abnormality is a lateral walk in which the natural sequence of four footfalls is disrupted and a pace like gait is exhibited whereby two diagonal footfalls occur. This style of walking is often caused by training techniques but can also be as the result of genetics or injury. Horses with an overly scopey natural walk, combined with a tight top line and back, may run the risk of developing a lateral tendency, especially when starting to ask for collection.

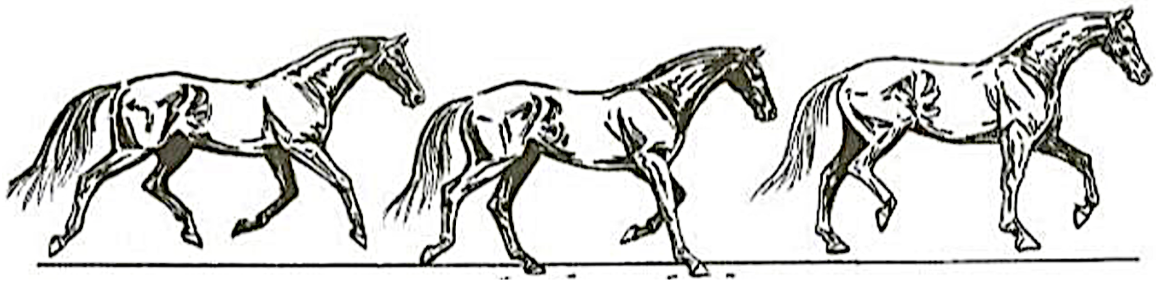
From a training perspective, the intricacies of the walk result in it being the most difficult gait to improve and this shows at all levels as it is at the pace of walk that imperfection of dressage are most evident (FEI). François de Lubersac considered the walk as the ‘‘*queen of gaits*’’ as its movement requires great precision and coordination.

Trot

The trot is a symmetrical two-beat gait with a diagonal footfall separated by an aerial phase. The back and barrel of the horse is most rigid in this gait as opposed to the other gaits.

A clear moment of suspension is a key element of an elastic trot using tendon strain energy for efficiency. However, suspension has no function with the tempo of the horse or with unnatural leg movement, as seen in various versions of extended trot nowadays. Horses that are trained to trot with its knees up eyeball level do not have suspension as this decreases stride length.





Although trot is defined as a diagonal gait, variations in diagonal footfalls can often be observed. These variations can be referred to as Diagonal Advanced Placement (DAP) or Diagonal Dissociation. Diagonal dissociation is generally not considered as lameness, but either a training or breeding condition. When the hind leg of the diagonal pair touches down before the diagonal front leg, it is known as positive DAP. When the front leg of the diagonal pair touches down before the diagonal hind leg, it is known as negative DAP (Clayton 2005).

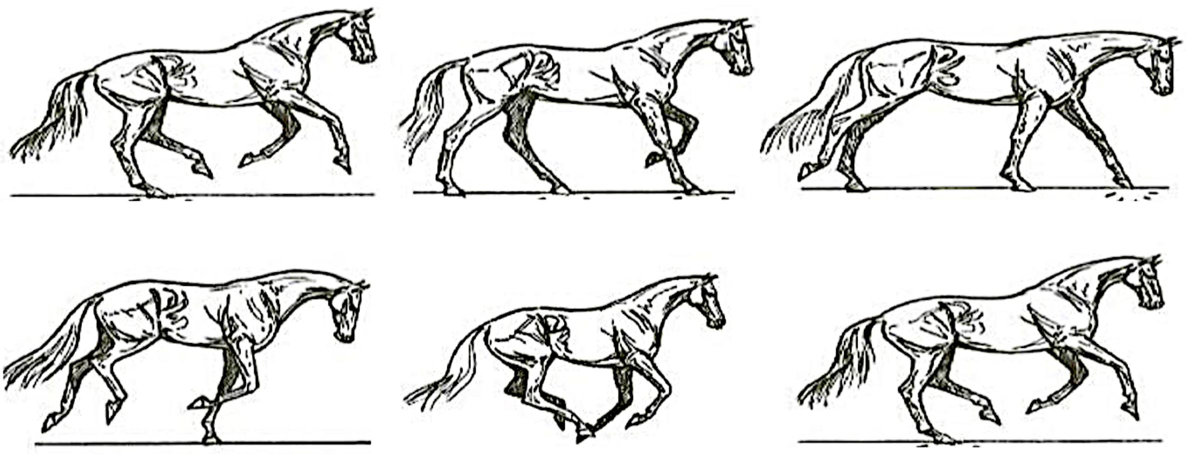
Negative DAP is an undesirable gait impurity as the horse is overloading the forehand, reducing biomechanical functionality and making it more susceptible to injuries. In Barbara Schulte's words: *''Let's stop breeding horses for thrust and hypermobility, and for the benefit of horses, concentrate on carrying capacity and stability instead.''*

Negative DAP: the right hind foot is already of the ground while the left front is still load bearing. Also note how the left hind has a lot of joint action without a gain in forward movement. A strong line of the external oblique is visible in combination with a hollowed lower back.

Canter

The canter is an asymmetrical three-beat leaping gait with transverse limb placements separated by an aerial phase. The canter displays a leading leg which can be described as either the first leading hind limb or the final footfall of the last front limb. As a result of the diagonal foot falls, the back must be aligned to maintain rhythm and engagement.

Scientific studies show a linear connection between canter velocities and lumbo-sacral joint movement (Johnson et al 2012). Therefore, this gait entails the most loin coiling and requires a healthy sacro-pelvic sling system to do so. Any canter that lacks correct sacro-pelvic engagement will seem downhill with the hindlegs trailing behind the body instead of under the body.



Diagonal dissociation has also been observed in this gait and is most referred to as a 'four beat canter'. This sequence of footfalls is noticeable when horses show a 'broken' diagonal pair landing on the ground at separate times. Extreme collection such as canter pirouettes often induces a four-beat canter, but in young horse competitions it is sometimes mistakenly confused with the concept of an uphill canter.

A four-beat canter in a youngster. This is often wrongly confused with being ''uphill''

A four-beat pattern is normal for a gallop in which the diagonal pair becomes naturally dissociated with the hind leg landing before the front leg. This raises the question, is a four-beat canter technically a gallop? Is the extreme movement bred in today's competition horses damaging the clarity of their basic gaits?

In addition to a four-beat canter, another common abnormality is a canter lacking suspension. In this case, the gait shows a three-beat purity, but the outside hind limb touches the ground to take off for the next stride before the inside leading front limb takes off into the air the finish the previous stride.

A canter lacking suspension can feel extremely comfortable, and thus can easily fool the rider into believing it is a healthy and organic canter but, it has major drawbacks, and the horse won't be able to correctly perform lead changes.

General lameness is difficult to detect in canter. Often, the horse changes leading legs to compensate and uses the diagonal pairing to support the compromised limb.

Due to the nature of the gait sacro-pelvic causes of lameness will be more evident in canter than any other gaits. Hence, when the cause of lameness is unknown it can be useful to include the canter in a lameness exam. When a horse is asked to move forward and they break into a canter it is a sign of unsoundness, often this is associated with the hindlimb but not always.

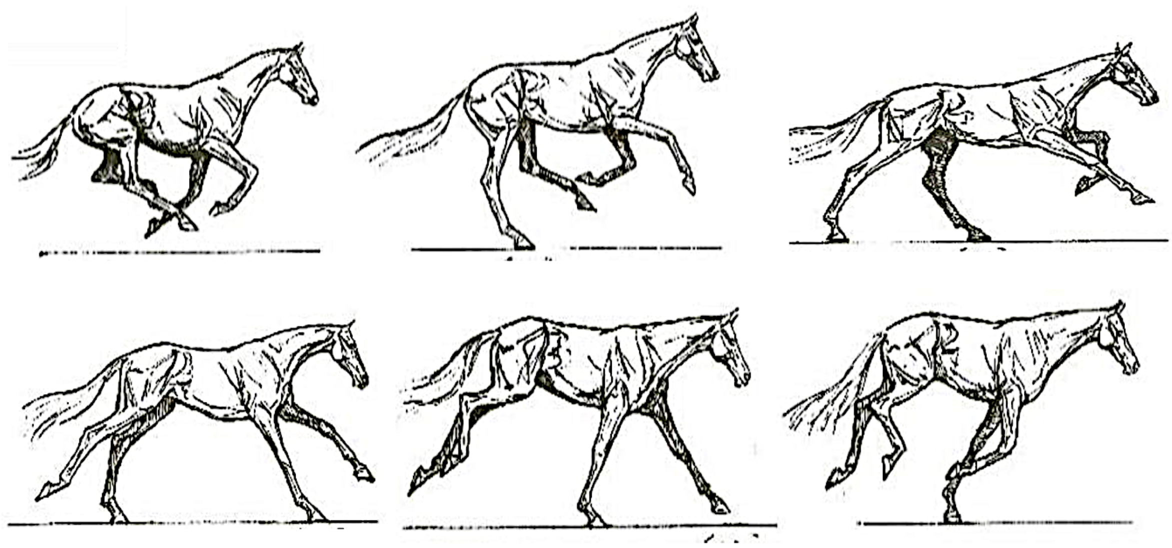
A horse showing a non-suspension canter

Gallop

The gallop is an extended gait with long strides and high forces. The head and neck oscillate back and forth in large balancing gestures while carrying the momentum forward.

The gallop is enabled due to physiological adaptations in the cardiovascular and respiratory system. A racing gallop can reach between 60-70 km/h and 260 heart beats per minute.

Like the canter, the gallop has a leading limb, but eventually the gait becomes rotational and stressful on the hip, stifle, and suprascapular nerve.



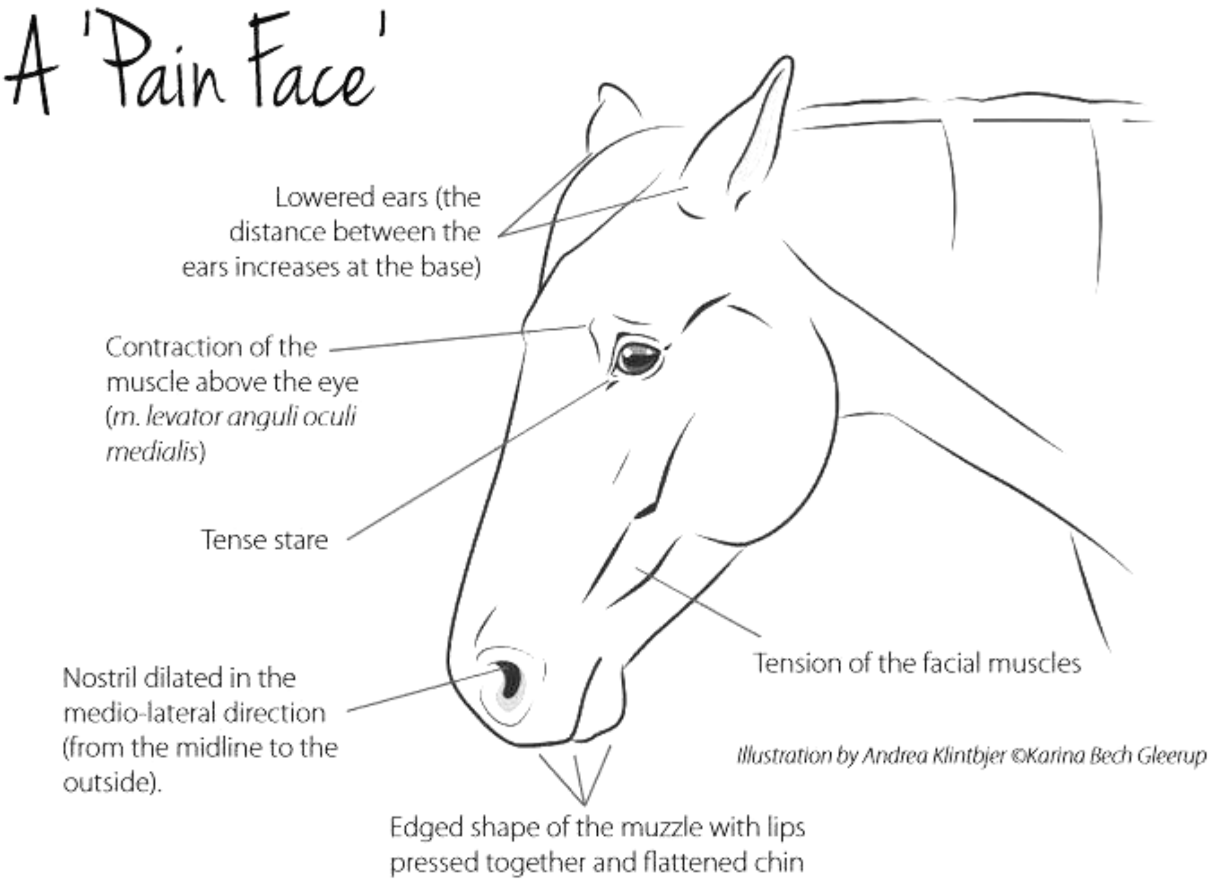
LAMENESS

Looking at the definition of lameness, it can be described as an abnormal stance or gait that is the result of dysfunction of the locomotor system. There can be multiple lameness's presenting in different circumstances and some lameness's are only obvious under specific conditions.

Lameness itself is a clinical sign and not a diagnosis. Lameness can be caused by:

- Pain & stress
- Mechanical restrictions
- Neurological dysfunction

Pain-related lameness can be classified as either weight bearing (supporting limb) or non-weight bearing (swinging limb) lameness. It can have many causes such as infection, joint pain, organ issues and so on. Pain experience is highly individual. It is possible that a scar can cause intermittent nerve pain in one horse leading to a lameness, where in another horse it might not be the case.



Picture adapted from Gleerup et. al (2015)

It is extremely important to try and learn to recognize pain and stress signals as much as possible to act timely and bring the horse back to a level of comfort as much as possible. The picture below can be a useful guide to recognize pain in horses.

Mechanical lameness is often qualified as being caused by a physical abnormality that prevents normal movement of a limb but does not necessarily cause pain.

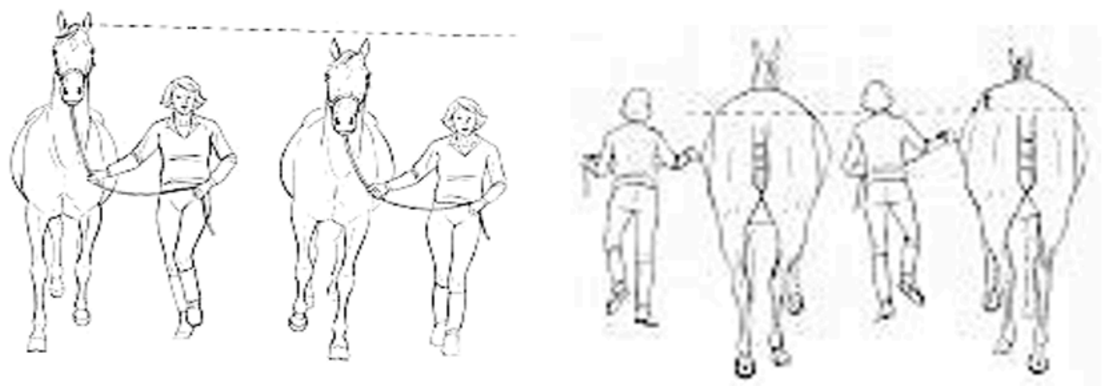
Neurological lameness are gait abnormalities caused by nerve compression or deviations.

Due to the individuality component, many causes of lameness do not produce a characteristic gait abnormality, making diagnosis a challenge. Ten different horses with the exact same issue might all develop a different gait abnormality in response to the issue.

In addition, the area where the lameness occurs can be a completely different area than where the cause is in the body, making it even more difficult to diagnose correctly. Rooney (1979) beautifully stated: *''the most common cause of lameness is lameness.''*

Lameness can be unilateral (one limb affected) or bilateral (more limbs affected). Unilateral lameness's are usually the easier to diagnose with common clinical symptoms including:

Unilateral weight bearing front limb lameness	Head bobbing: Head up on load bearing lame limb Head low on load bearing healthy limb
Unilateral Weight bearing hind limb lameness	Hip-hike (uneven lift hind feet) Acute lameness: hip higher on lame side Chronic lameness: hip higher on healthy side Head bobbing opposite pattern to front limb lameness
Neurological lameness	Inconsistency in gait pattern Coordination issues



Left head bobbing. Right: hip hike

Most lameness's are bilateral in nature to compensation patterns. No grading scale can be utilized for a bilateral symmetrical lameness, the horse may show subtle shortening of stride and nerve block in one limb may show up the lameness in the other limb.

Four limb lameness is generally the hardest to detect. In this case, lameness might be missed because an abnormal movement pattern on all four feet might appear as normal.

To assess for stride abnormalities check:

- **Hoof placement** → Placement of the hoof in relation to each hoof print, observing
  for deviation away from the ideal that is placing load bearing strain elsewhere on
  the body. Straightness and symmetry.

- **Sole presentation** → How much of the sole can be seen.

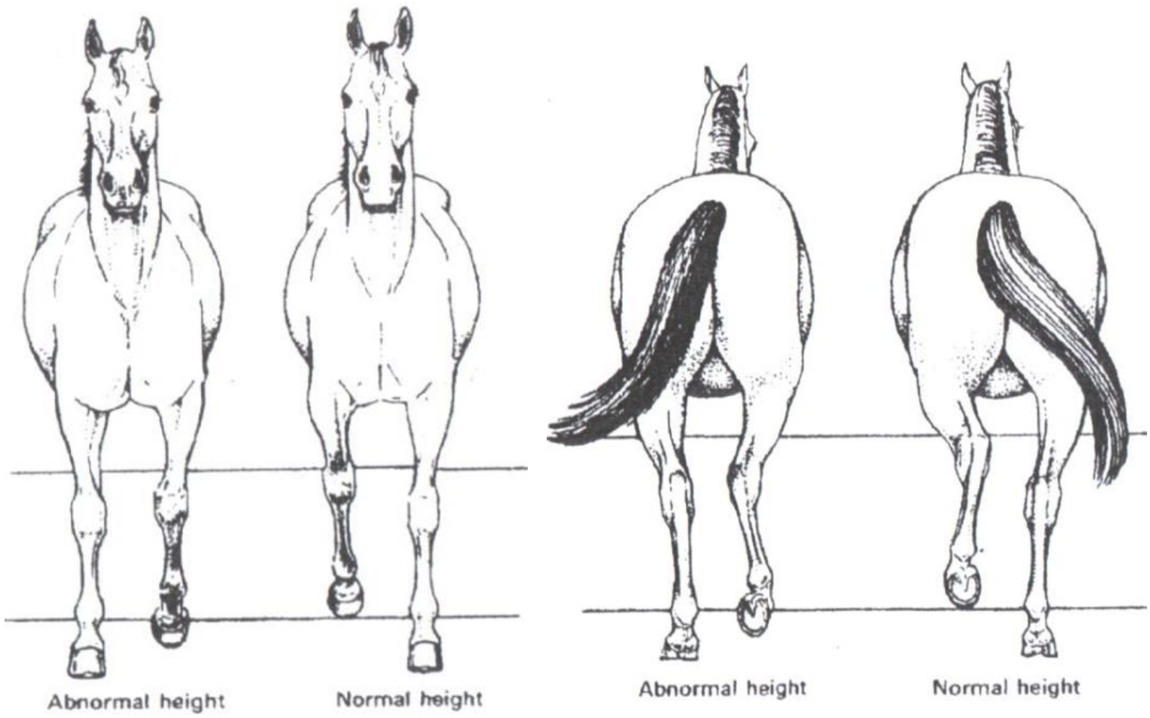
- **Toe height** → How far is the toe coming off the ground in all phases of the stride

- **Arc of the stride** → through the swing phase of the stride

- **The upside-down V** → Observe the symmetry and size of the upside-down 'V'
  in between the front legs and hind legs. This will indicate the length of stride.

- **Movement of each joint** → even energy distribution through the joints.

- **Bony landmarks** → position, movement, and symmetry.



Abnormal Stride length may be recognized by the failure to extend or lift a limb to the normal height.

Have a point of reference for each joint – bony landmarks.

Walk and trot are generally the gaits that show lameness the most. Limb lameness is hard to detect in canter. Very often, the horse changes leading legs to compensate and use the diagonal pairing to support the compromised limb.

A lameness caused by sacro-pelvic problems might become more evident in the canter. The canter will appear difficult, tense and the horse might lose gait purity. Bunny hopping; cross canter; problems with speed control; crookedness.

For a more thorough explanation on gait analysis, please watch the video series in Module 2. Biomechanics.

Surfaces

Hard surface	Increases concussion through the bone Will accentuate joint pain – especially in the lower limb and back
Soft surface	Increases strain on soft tissue Will accentuate a toe drag and hip joint rotation
Slope	Accentuates general lameness and joint problems – especially elbow
Circle (lunge size)	May accentuate forelimb lameness on the inside limb if below the knee May accentuate forelimb lameness on the outside limb if higher in the limb. Accentuates toe drag Accentuates hind limb lameness through the arc of the stride – but cannot be utilized to look at sacro-pelvic symmetry
Ridden	May accentuate or hide a lameness depending on the rider and training of the horse.

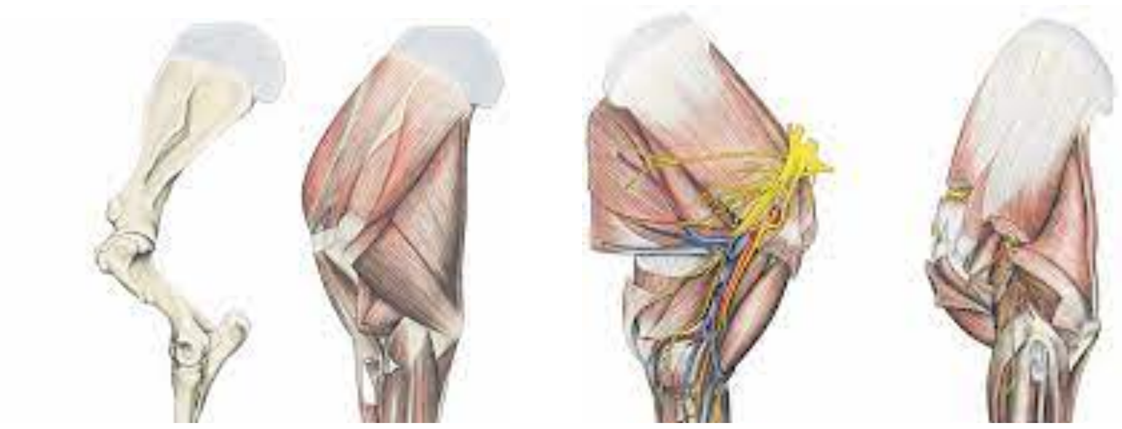
JOINT ACTIONS

To accurately analyze movement, it is important to observe the action of joints. Below, all joint actions will be specified separately going from front- to hind end.

Shoulder

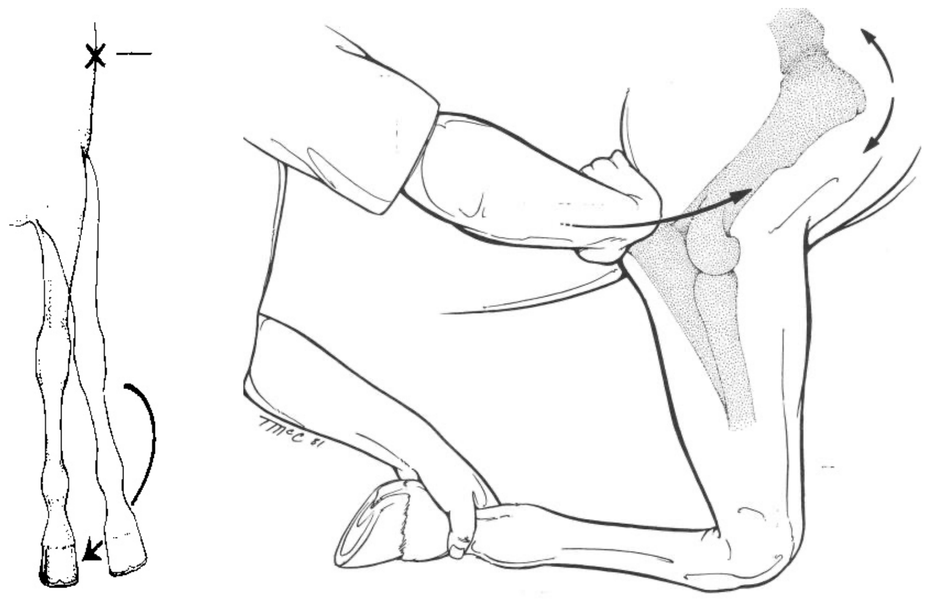
The shoulder joint is the articulation between the *glenoid cavity* of the scapula and the head of the Humerus. It is a ball and socket joint which allows for flexion, extension, circumflexion, and rotation. The joint moves in flexion during stance phase and extension during swing phase, where it slides against the ribcage in both forward and backward movement. Abduction and adduction of the shoulder joint becomes clear during lateral movements.

The shoulder joint has no collateral ligaments governing its range of motion and thus solely relies on muscles and its associated tendons to coordinate movement in this region.



Important muscles for smooth shoulder joint action include the Serratus Ventralis, Trapezius, Rhomboid, The Pectorals, Brachiocephalic, Deltoid, Supraspinatus, Infraspinatus, Teres Major, Teres Minor, Biceps Brachii and Triceps.

Due to the relative superficiality of the supra scapular nerve, it can become compressed due to poor posture or trauma. This condition is also known as sweeney and leads to atrophy of the Supraspinatus and Infraspinatus muscles and results in an abnormal prominence of the shoulder joint and spine of scapula. As a result, the affected shoulder and front limb display an outward rolling – or rotational – action as the horse moves. Treatment via electro stimulation has proven to assist in rebuilding muscle tone and function.

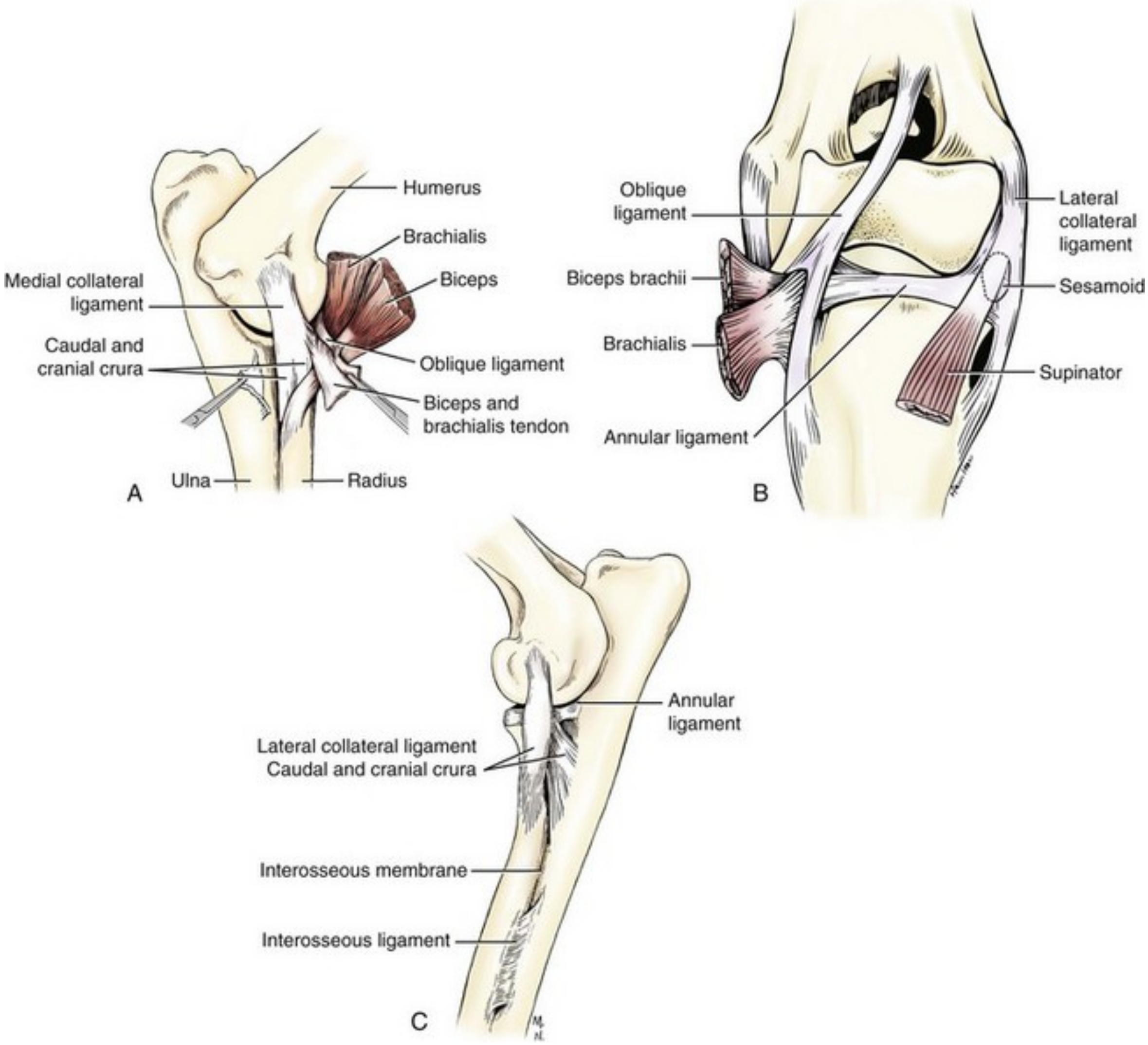


Left: shoulder joint issues often lead to gait abnormalities best seen from the front. Right: elbow assessment for rotation

Elbow

The elbow is a hinge joint located between the carpus and shoulder. It consists of three bones: Humerus, Radius and Ulna. In a normal standing position, the elbow lies between 140-150 degrees at the dorsal angle and is braced in this position by collateral ligaments and muscular co-operation to ensure effective movement.

The elbow mainly moves in flexion and extension, with some slight rotation possible: *''In flexion, the collateral ligaments loosen allowing the radius and ulna to slightly rotate outwards due to the structural nature of the trochlear groove in the distal Humerus and the action of the anconeal process into the olecranon fossa.''* – Butler 2017

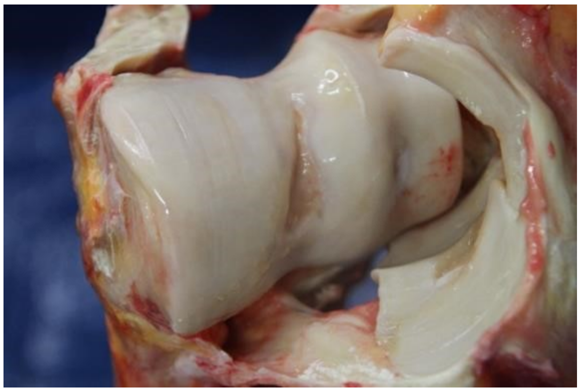


Important muscles for smooth elbow action include Triceps, Tensor Fasciae Antebrachii, Anoneus, Biceps Brachii and Ulnaris Lateralis.

A 2016 paper by Sharon May-Davis demonstrated that worn-out lesions in the elbow occur in 100% of ridden and driven horses to a varying degree within three months of training.

The lesions ''*appear worse on the same side as an upright foot or compromised inferior check ligament (…) the action looks like a slip and/or double 'clunk (…) The actual change in the action begins when the front leg is in the stance phase during the stride as the limb goes into the posterior phase of the stride. It is more obvious going down a hill…As such, the muscles around the elbow joint brace under load and in particular, the Lateral Triceps muscle, which can become quite painful under palpation.''*
- May-Davis 2016

The action of the elbow is best assessed on a slight incline.



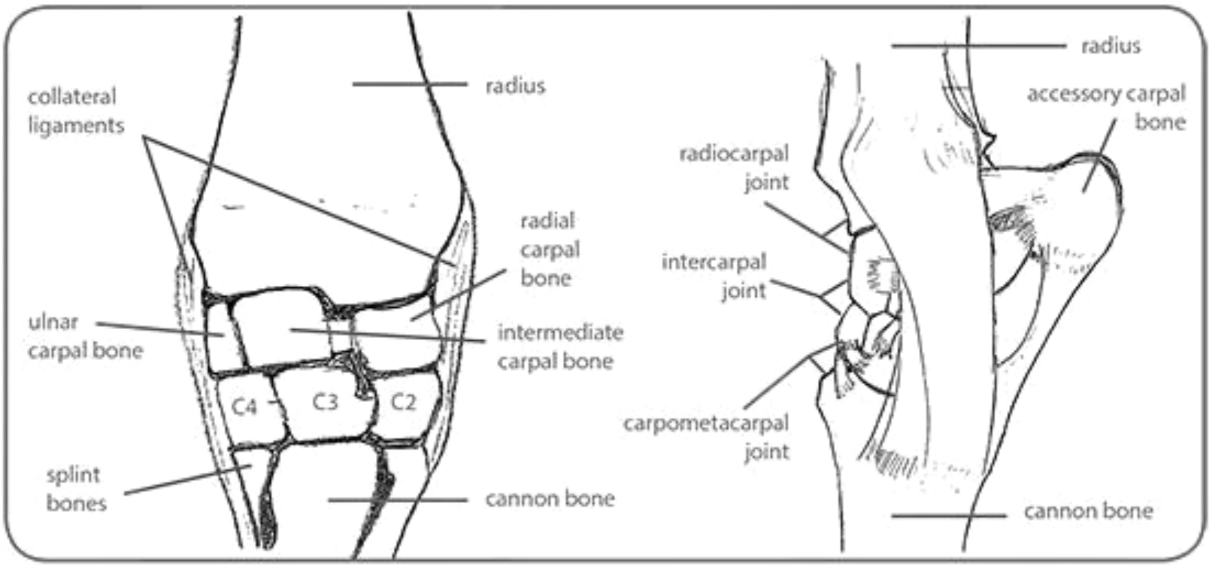
Left: assessment of the elbow downhill. The horse showed a double clunk motion. Right: the elbow of the same horse upon dissection presenting worn-out lesions and inflammation.

Carpus (front knee)

The carpus is a hinge joint between the radius, two rows of carpal bones and the 2nd - 4th metacarpals. It is one of the most complex regions in the front limb because there are several small bones and ligaments all combining to form the three main joints: the antebrachiocarpal joint, the middle carpal joint, and the carpometacarpal joint.

t moves exclusively in one plane – flexion or extension - noting that the carpals glide within the joint to allow this range of motion. Overextension is prevented by occlusion of dorsally located stop facets on the rows of carpal bones, and by the support of a stay apparatus (Deane & Davies 1994).

The carpus rapidly snaps into the close-packed position after initial ground contact, and this allows the fore limb to function as a propulsive strut throughout most of the stance phase (Clayton 2015).



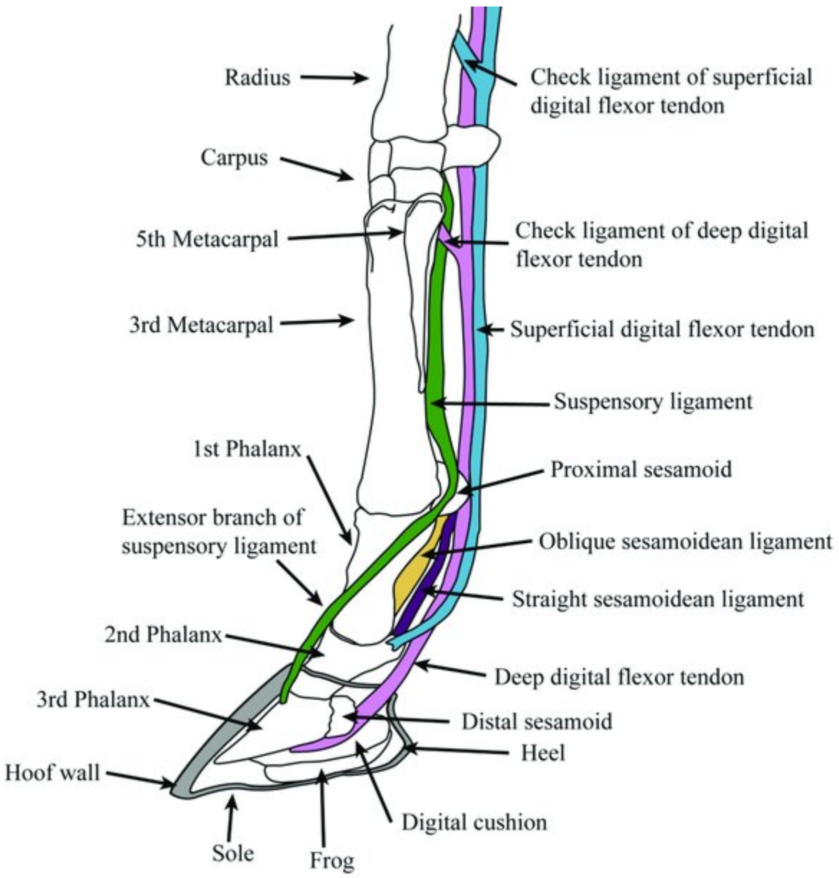
There are no direct muscles from the knee below, only tendons and ligaments that connect to their respective muscle bellies higher up the limb. The most important structures surrounding the carpus include superior check ligament, extensor, and flexor carpi radialis, ulnaris lateralis, digital flexor and extensor tendons, and the suspensory ligament.

Left: a clear rotation and all carpal joints are visible. Right: healthier knees and straighter flight arc.

The carpal bones should not be visible from the outside and ideally, no offset, deviation or rotation presents. Abnormalities in the carpus are often presented as paddling and plating or ''knuckling'' lover the joint.

Fetlock

The fetlock is another hinge joint located between the 3rd metacarpal and 1st phalanx in both the front and hind limbs of the horse. It allows for flexion and extension as its range of motion. The sesamoidial apparatus along with strong collateral ligament prevents overextension of the joint.



The fetlock joints and the palmar soft tissues behave like an elastic spring to conserve energy. In the early part of the stance phase the fetlock joint extends as it sinks toward the ground, reaching maximal extension at midstance, which corresponds with the time when the cannon bone is vertical. As the fetlock joint extends, the palmar soft tissues are stretched. After midstance the fetlock rises allowing the elastic structures to recoil, thereby releasing elastic energy that was stored during the stretching process. This energy helps to flex the distal joints during the swing phase.

Because of its function, racehorses are statistically most vulnerable to fetlock injuries. However, fetlock issues are becoming more common within other disciplines too. A common visual sign is hyperextension – or dropping – of the fetlock during movement.

A common cause for this is modern breeding programs which aim to achieve maximum agility. Excessive freedom of movement – hypermobility – creates large spectacular movement and an unprecedented athletic capacity in lateral movements. While this is visually spectacular, it is a painful condition which causes them to struggle for general balance and stability.


Left: healthy recoil in the fetlock. Right: overextended dropping fetlocks

When one fetlock drops more than the opposite fetlock, it is possible that weight-bearing lameness may be present – often appearing in the opposite limb. Alternatively, a fetlock may show excessive drop if there has been damage to the structures in the leg. Finally, a common condition causing this movement is often referred to as ESPA – known as DSLD or Degenerative Suspensory Ligament Desmites.

Pastern

The pastern is located between the 1st - 2nd phalanx and incorporates the short and long pastern bones which are held together by two sets of paired ligaments to form the pastern (proximal interphalangeal) joint. It has limited range of motion due to multiple ligamentous attachments which include collateral ligaments that are supported further by extensor and flexor tendons. Although the joint has limited movement, it supports in dispersing the concussive forces of the horse's stride and influences the flexion and extension ability of the entire limb.

The pastern plays a pivotal role in shock absorption. When the horse's front leg is grounded, the elbow and knee are locked. Therefore, the fetlock and pastern, excluding the hoof, are the joints responsible for all the absorption of concussive forces of a footfall. Together, they effectively distribute these forces among both the bones of the leg and its respective tendons and ligaments.

The slope of the shoulder should ideally match the slope of the pastern and the angle of the hoof post trimming. Ensuring an appropriate and equal angle ensures that the bones of the pastern and coffin joints remain in correct alignment, with a straight line running through their core. An angle broken forward or back increases the stress on these bones, joints, tendons, and ligaments and alters the movement pattern.

Long sloping pasterns are naturally occurring in thoroughbreds and warmbloods. Short, upright pasterns are more commonly associated with cold bloods, quarter horses and less commonly in warmbloods.

Coffin joints

The coffin joint is located between the 2nd - 3rd phalanx and exhibits a range of motion like the fetlock with the distal sesamoid and navicular, behaving as a suspensory apparatus.

Lumbosacral

The lumbosacral joint is the articulation between the last lumbar and the sacrum. It is a highly specialized joint that with a high range of motion for flexion and extension:

''The lumbo-sacral joint, is uniquely structured so that lateral flexion is almost impossible, while up-and-down coiling and uncoiling motion is promoted (…) Loin-coiling initiates a cascade of postural changes along the vertebral chain from back to front: the free span of the back arches, the base of the neck is raised, and the animal makes the 'neck-telescoping gesture (…) Therefore, the lumbosacral joint is the key to athletic ability in horses.''

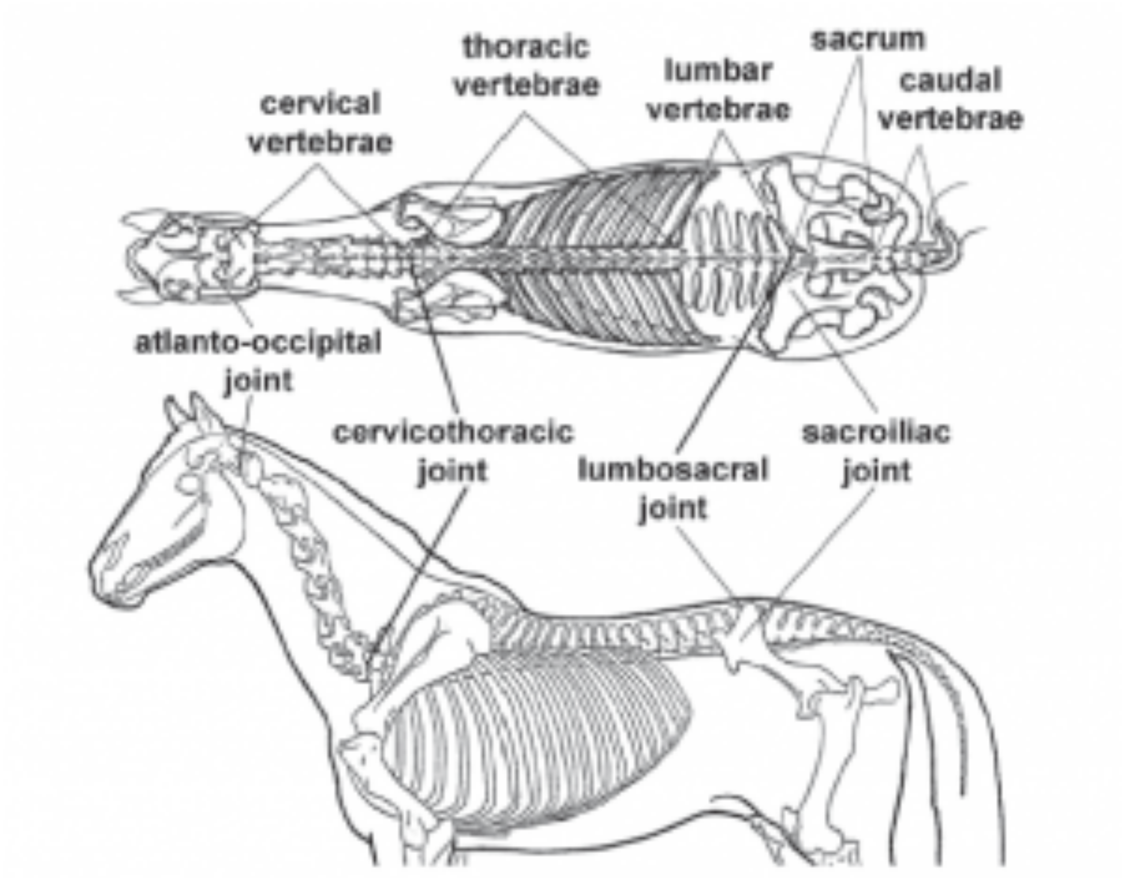
– Bennet 2018

The lumbosacral joint is supported by sacro-pelvic ligaments and muscles including the iliopsoas, quadratus lumborum and the sacroiliac ligaments.

Sacroiliac

The pelvis forms the link between the vertebral column and the hind legs through the sacroiliac (SI) and hip joint. The SI joint is a small, flat, and synovial joint that attaches the wing of the sacrum to the ilium of the pelvis at a 30-degree angle.

It is primarily ligamentous in its attachment and performs a stabilizing function for the horse and helps with transferring forces from the hind limbs forward through the spine. The SI has a limited range of motion that only allows for minimal flexion and extension depending on the relative position of the pelvis.



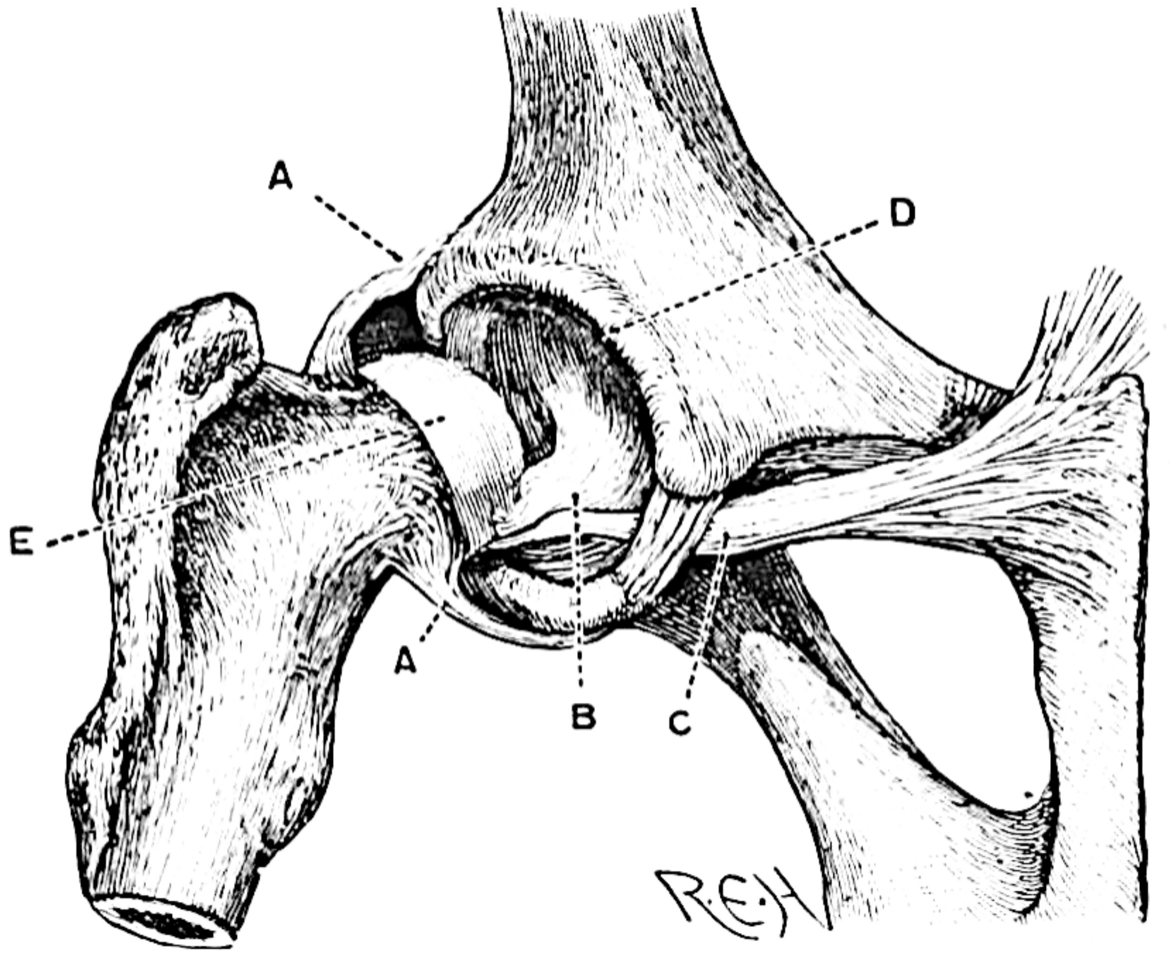
The sacroiliac is particularly inaccessible due to its depth within the pelvis and surrounding musculature, making it impossible to palpate the joint externally (Goff 2018).

Hip

The hip attaches the femur to the pelvis. In contrast to the rigid SI joint, the hip is a highly mobile ball and socket joint that allows for range of motion in every direction. It is pivotal to movement as hind end biomechanics is largely dictated by the ability to rotate around the hip joint.

The hip joint is protected, stabilized, and assisted by a layer of fat, [accessory] ligaments and large hind end muscle groupings. These muscles often perform multiple functions, creating close interconnection with the hock and stifle.

For example: Rectus Femoris [quadriceps] flexes the hip while extending the stifle.   Semitendinosus [hamstrings] extends the hip and hock joints



while flexing the stifle. Biceps Femoris [hamstrings] extends the hip, stifle, and hock, and flexes the stifle. Tensor Fasciae Latae flexes the hip joint and extends the stifle while tensing the Fascia Latae. Iliopsoas flexes the hip joint and rotates the femur.

Inflammation and degenerative changes in the hip joint are very common in horses, but highly underestimated due to diagnostic challenges. Personal experience from 40+ whole horse dissections demonstrated that 9 out of 10 horses suffer from hip joint problems to a certain degree.

Due to diagnostic challenges, clinical assessment is very important to recognize dysfunction. A common symptom that indicates towards hip joint issues is the presence of a clear rotation with the hoof is on contact with the ground on straight lines and circles. Usually, soft surface worsens the tendency.

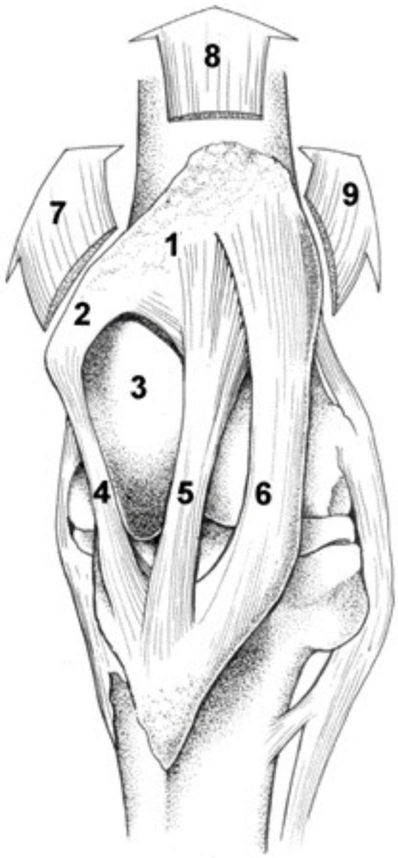
Stifle

The stifle is commonly known to be the most complex joint in the horse's body. The stifle is located between the femur and tibia - medial and lateral compartments. It consists of two joints: the femoropatellar joint and the femorotibial joint, with lateral and medial compartments. ''*There is a complex arrangement of soft tissue in the stifle – 12 ligaments, 2 menisci and numerous musculo-tendinous support structures – that provide functional stability, force transduction and locomotion.''* - Fowlie et al. 2012

The stifle is a hinge joint that moves in flexion and extension combined with accessory outwards rotation when the limb is in the flexion phase. This is to clear the barrel when moving: ''*The femur is designed to allow outward rotation whilst supported by the two menisci of the tibia. The patellar glides between two trochlear ridges and aids rotation with this action whilst providing stifle extension. ''* - May-Davis 2015

The stifle and the hock have a reciprocal arrangement and are synchronized in their movements through the *superficial digital flexor* muscle and the *peroneus tertius* muscle. I.e., When the stifle flexes, the hock flexes, when the stifle extends the hock extends.

Similarly, to the hip, the stifle is also closely related to the lumbar spine due to muscle connections which are innervated from L3-S2. A common sign of stifle issues is a 'roached' back in the lumbar area. Due to stiffness in the stifle, the horse cannot engage the hind limb which results in a brace in the lower back. The Psoas Major, – a major hip flexor, then usually gets overworked pushes up against the lumbar spine resulting in a so-called 'roached back'.



This example emphasizes the overlap of the muscles involved in the movement of the stifles are also involved in the movement of the hips. Hence, this shows that a problem in any of those joints can easily affect the others. It is therefore advised to observe 'hip, hock and stifle' all together. The difficulty is then trying to localize the primary cause of the problem.

A notable feature of the stifle is the stifle's locking mechanism that is part of the horse's stay apparatus. A locked stifle joint occurs when the patella (1) with the parapatellar fibrocartilage (2) is hooked over a ridge on the head the of the femur bone – the medial ridge of the femoral trochlea (3), by means of the patellar ligaments (4-6).

The *rectus femoris muscle,* inserting to the patella, functions to flex the hip whilst extending the stifle joint. It may assist in keeping the patella in a locked position. The patella is released by Quadriceps contraction and Tensor Fasciae Latae and Biceps Femoris lateral pull.

Complications arise when the patella fails to unlock when the horse want to flex the limb. This common condition is called upwards fixation of the patella or locking stifle. Clinical signs of an upward fixation of the patella include:

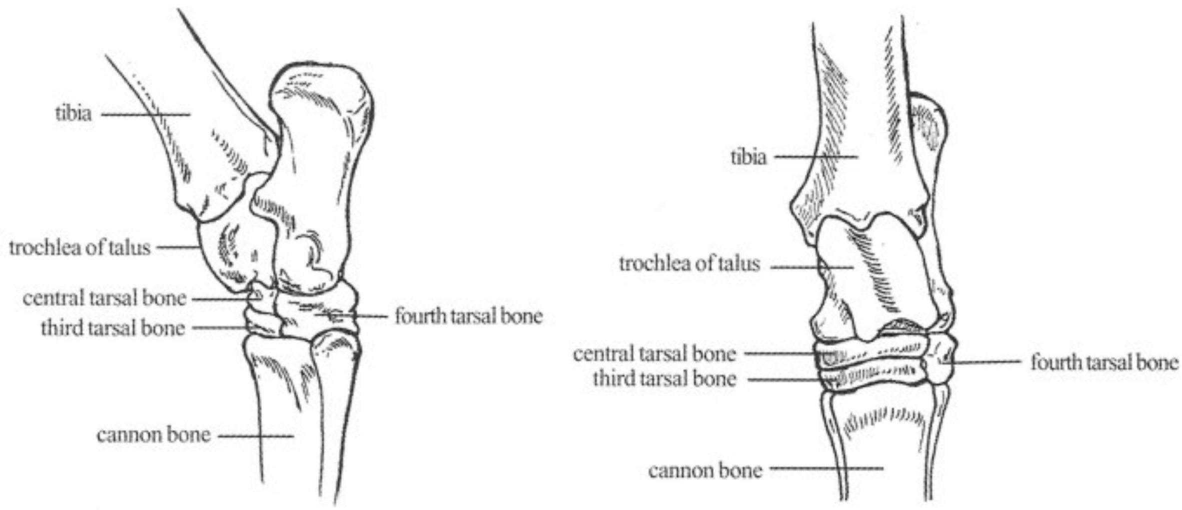
Hind limb locked in extension	Dragging of the toes
Feet to the outside	Shortened / stiff stride hind limb
Clunking of clicking noise	Hindquarter muscle wastage
Cramping - can look like stringhalt	Swelling, pain & inflammation
Problems going downhill	Roach back

The condition can be improved through mobilization techniques, taping and rehabilitation training with a focus on strengthening supporting muscles and functioning of the sacro-pelvic sling.

Hock

The hock or tarsus is a hinge joint located between the tibia and cannon bone of the horse's hind limb. Although the hock is often referred at as if it were a single entity, it is a complex apparatus and regarded as one of the hardest working joints in the horse's body.

The hock consists of four joints – supported by various ligaments. The top and largest is the *Tibio-tarsal joint* which is a 'high motion but low concussion' joint responsible for 80-90% of the total flexion/extension movement within the hock. The three smaller hock joints in descending order are the *proximal Inter-tarsal, distal Inter-tarsal and Tarso-metatarsal joints*. These 'low motion high concussion' joints make up for 10-20% of total movement.



The hock primarily allows flexion and extension as its range of motion, but it also has accessory medial, lateral, and rotational motion. The 3 degrees of translation are more pronounced at the trot.

The hock apparatus has a key function in shock absorption. As a result of the horse's anatomy, the hock joints are always under a certain degree of flexion in the early stance phase, enabling it to absorb concussion from the shock waves that directly travel up the limb and the rotational force [torque] produced by the break over phase of the stride. In the later part of the stance phase, the hock extends as it generates propulsion to drive the horse forwards.

Since the hock plays such a major part in the generation of power to jump and gallop, as well as to 'sit' in dressage, it is prone to both degeneration and injury. The lower joints are the most common source of lameness in horses because they are under significant stress in a working horse. The most common problems around the hock include thoroughpin, bog & bone spavin, osteochondritis dissecans (OCD) and osteoarthritis.

NEUROLOGICAL ASSESSMENT

The main purpose of the neurological examination is to determine whether there are neurological abnormalities or proprioceptive deficits present.

Proprioception is the subconscious awareness of the relative position of the body, their relationship to each other and the surrounding environment. It enables the maintenance of balance and control regardless of gait or type of work being performed and the need to consciously look at it or process the information.

Proprioception is facilitated by mechanically sensitive proprioceptor and sensory neurons distributed throughout the horse's body. A horse possesses three basic types of proprioceptors:

- Muscle spindles - these are embedded in skeletal muscle fibres
- Golgi Tendon organs - these lie at the interface of muscles & tendons
- Joint receptors - these are embedded in joint capsule

The sensory systems of the horse include:

- Visual perception - The ability to interpret the surrounding environment using light in the visible spectrum reflected by the objects in the environment. The resulting perception is also known as (eye)sight or vision.

- Vestibular system - provides the leading contribution to the sense of balance and spatial orientation for the purpose of coordinating movement with balance. It consists of the semi-circular canals which indicate rotational movements and the otoliths which indicate linear accelerations.

The central nervous system integrates the information received from those proprioceptive and sensory neurons to create proper spatial awareness. Proprioceptive deficit shows in the loss of spatial awareness of the body, limbs and/or head. It alters gaits and movement in a way that cannot be explained by changes in the limb. A neurological exam consists of:

- Observation
- Reaction tests
- Reflex testing

Overall markers:

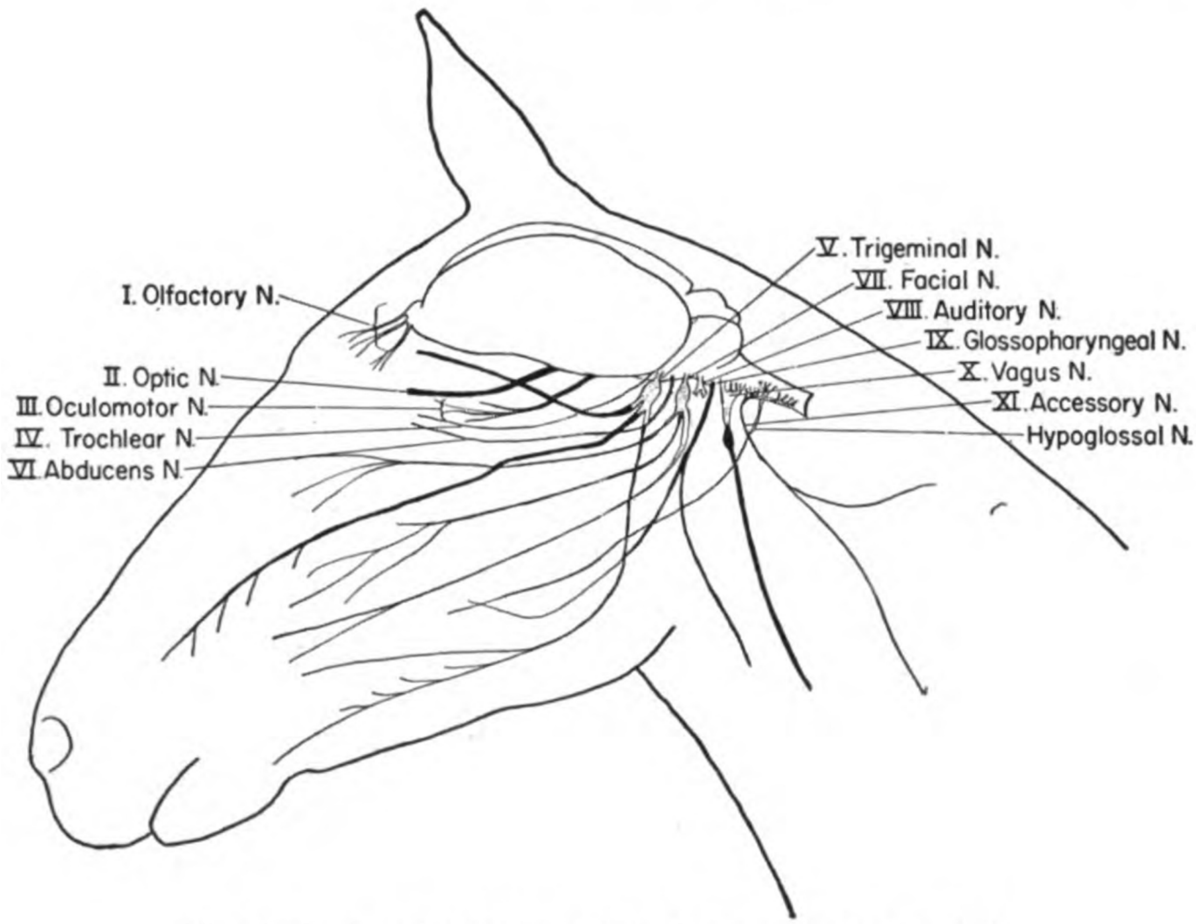
- Mental status
- Coordination
- Reactions

Reflexes are involuntary or automatic actions in response to a stimulus. A reflex does not receive or need conscious thought as it occurs through a reflex arc. The reflex arc acts on an impulse before it reaches the brain.

A neurological assessment can be structured as following:

- Evaluating mental status
- Assessing cranial nerves
- Assessing spinal reflexes
- Assessing muscles
- Assessing gait & posture

There are 12 pairs of cranial nerves help the horse taste, smell, hear and feel sensations. They also assist in making facial expressions, blinking of the eye, and moving of the tongue. Cranial nerve abnormalities can be intracranial lesion or peripheral, i.e., direct trauma or guttural pouch disease. An assessment of the cranial nerves' tests mental activity, head posture and coordination and reflexes.



The table below is adapted from Johnson 2010 and summarizes how to assess cranial nerve functions.

Cranial Nerve	Function	Assessment	Lesion
I Olfactory	Smell	Monitor nostrils Carrot test	
II Optic	Vision	Menace response Pupillary light reflex	Blindness Loss of PLR
III Oculomotor	Pupil constriction Extraocular muscles	Pupillary light reflex Eye position Palpebral fissure size Medial globe motion	Lateral / ventral strabismus, ptosis, mydriasis, and loss of PLR
IV Trochlear	Extraocular muscles	Eye position	Dorsomedial strabismus
V Trigemnial	Sensory to head Mastication muscles	Palpebral blink Head touching Chewing, jaw size, muscle development	Loss of sensation, palpebral and corenal reflex. Muscle atrophy and dropped jaw.
VI Abducent	Extraocular muscles	Globe retraction Lateral globe motion	Medial strabismus and loss of corneal reflex
VII Facial	Facial expression muscles	Facial symmetry Palpebral blink	Facial paralysis, Loss of palpebral

	Parasympathetic to salivary and lacrimal glands	Ear, muzzle, and lip movement	reflex and blink, Dry eye
VIII Vestibulocochlear	Posture and Balance Hearing	Head and eye position, physiologic nystagmus Response to noise	Head tilt, nystagmus loss of balance, Deafness
IX Glossopharyngeal	Sensory and motor to pharynx and larynx	Ability to swallow	Dysphagia and displaced soft palate
X Vagus	Sensory and Motor to pharynx and larynx	Ability to swallow Laryngeal movement	Dysphagia, laryngeal paralysis, and displaced soft palate
XI Spinal Accessory	Motor to cervical muscles, larynx, and esophagus	Cervical muscles	Muscle atrophy
XII Hypoglossal	Motor to tongue	Tongue strength and symmetry	Tongue atrophy and paralysis

Spinal reflexes include:

- Skin sensation - hyperesthesia or hypoalgesia
- Panniculus reflex – cutaneous trunci reflex
- Tail tone reflex – gently lifting the tail head
- Perineal and anal reflex – reaction to tapping

Markers for neurological muscle evaluation include:

- Abnormal sweating
- Abnormal twitching
- Flaccid versus hypertonic

Finally, a neurological posture and gait assessment consists of various tests to check the body's reactions including:

- Stance – checking for unbalanced positions
- Placing – placing limbs crossing one another and check response time for the horse to place them back in natural position.
- Sway test – pull the tail gently to the side when walking a straight direction
- Tight circles, agility course, ability to back-up and handle uneven ground

Potential indicators of a neurological problem in movement can be:

- Tripping
- Falling
- Lack of coordination
- Tremors

Type of ataxia

When a horse tests positive in a neurological exam it is sometimes also referred to as ataxic. Ataxia is not a diagnosis, but simply an umbrella term that describes the presence of neurological abnormalities. Low grade hindlimb ataxia can mimic hindlimb lameness and both can be present. Mild ataxia can create a bouncy, croup high, stiff legged hindlimb gait on a downward trot to walk transition with irregular height of steps.

The hind feet may be placed more deliberately on the ground with sideways movement of the foot. There may be toe dragging and a lack of hind limb impulsion. The horse might have a croup high canter on the lunge.

Types of ataxias are specified in the diagram on the next pages.

Localization	Limbs involved	Symptoms
Cerebellum	Bilateral lesion – 4 Unilateral lesion – 2- ipsilateral	Spastic, dysmetric. Loss of control of rate, range, and force of motion. Strength maintained. Head & Neck intention tremors. Tendency to rear.
Vestibular system	Peripheral – no proprioceptive deficits Central – proprioceptive deficit on ipsilateral 2 (front & hind)	Loss of posture and balance; Drifting, leaning, circling, falling to one side (worse when blind folded); Head tilt. Recumbent horses seem to prefer to lie on the affected side.
C1-C5/6	Bilateral lesion – 4 Unilateral – ipsilateral 2	Loss of proprioception; toe dragging; delayed protraction; knuckling; crossing over; stepping on the other foot; pivoting or circumduction upon circling; uneven stride; elongated stride (EMN paresis) in all four limbs.
C6-T2	As above	Loss of proprioception as above (more evident in hind limbs). Short,

		choppy stride with pronounced weakness in forelimbs (LMN paresis). Elongated stride in hindlimbs (UMN paresis)
T3-L3	Bilateral lesion – both hind limbs Unilateral lesion – ipsilateral hind	Loss of proprioception in hind limbs (as above). Elongated stride in hindlimbs (UMN paresis)
L4-S1	Bilateral lesion – both hind limbs Unilateral lesion – ipsilateral hind	Short choppy stride with pronounced weakness in hindlimbs. Hind end may buckle or collapse

CONCLUSION

You made it to the end of this manual! I hope you have enjoyed it.

In summary, we can define biomechanics is the continuous study of the movement of the horse – of each individual horse. Biomechanics is a fluid concept. To differentiate between what is normal, what is a variation and what is abnormal you need knowledge of anatomy as well as using your senses of sight, hearing, touch, and smell to properly assess each horse.

Today, it is difficult to find 'normal' biomechanics. Hence, I hope, that through spreading this knowledge that a change will occur in how we breed horses. In the meantime, I hope that you now have some tools on how to better read your horse 'inside-out'.

LIST OF TERMS AND ABBREVIATIONS

Abduction	Movement of a body part away from the midline of the body (mid-sagittal plane)
Adduction	Movement of a body part towards the midline of the body (mid-sagittal plane)
Agonist	The active one. Refers to muscle action
Anatomy	Branch of science concerned with the bodily structure of a living organism
Antagonist	The opposing one. Refers to muscle action
Appendicular	Part of the skeleton that consists of the thoracic (front) and pelvic limbs, including the pelvis
Aponeurosis	A tendinous sheet that attaches muscle to other tissue
Articulate	Divided into or united by two joints and moveable
Atlas	The first cervical vertebrae (C1)
Atrophy	Wastage of tissue. Muscles display a loss of mass and tone
Axis	The second cervical vertebrae (C2); A straight line about which rotation occurs
Axial	Part of the skeleton that includes the skull, vertebrae, ribs and sternum
Ballistic contraction	Ability to contract with momentum allowing fast movement to produce a larger range of motion.

Balance	The ability to control equilibrium – either static or dynamic – in relation to gravity only.
Bursa	A capsule like structure filled with synovial fluid
Biomechanics	The study of the mechanical principles of a living body. It includes and both kinematics – motion - and kinetics - forces
Bipedal	A portion of the stride in which two limbs support the body
Concentric contraction	Muscle shortens generating tension
Conformation	Describes body characteristics derived from breeding such as hair color, length and size of skeletal structure.
Costal	Relating to the ribs
Coxofemoral	Relating to the hip
Centre of mass	The point about which the total mass of a body is evenly balanced
Cervical	The anatomical name for the neck
Circumduction	A circular movement that consists in part of all the previous actions except for rotation. E.g., a horse that plaits or paddles

Diagonal Advanced Placement DAP	When the hooves of a diagonal pair of limbs do not contact the ground at the same moment.
Dorsiflexion	Upward flexion of the foot at the pastern
Dynamics	The branch of dynamics that deals with motion and the way in which forces produce motion.
Eccentric contraction	Muscle lengthens as it generates tension
ECVM	Equine Complex Vertebral Malformation.
Equilibrium	A state of zero acceleration where there no change in the speed or direction of the body.
Extension	To extend or open the angle of a joint
Extrinsic	Operates outside e.g., forelimb muscles with insertions on the trunk
Fascia	A fibrous collagen tissue that wraps around everything in the body.
Force	The mechanical action or effects of one body on another, which causes the body to accelerate relative to the inertial reference frame.
Flexion	Closing the angle of the joint. E.g., carpus, elbow, intervertebral joints.
Foramen	Perforation or hole in the bone to allow vessels to pass through.

Holistic Characterized by the belief that the parts of something are intimately interconnected and explicable only by reference to the whole.

Hypermobility Congenital disease with too much stretch in supportive soft tissue.

Frontal plane Any plane passing longitudinally through the body from side to side, at right angles to the median plane and dividing the body into dorsal and ventral parts. Also referred to as dorsal or coronal plane

Ground Reaction Force: The force exerted by the ground against a limb that is in contact with the ground. Acts in opposition to the force exerted by the limb against the ground

Hypertrophy Increase of tissue. Muscles display show an enlarged mass and tone

Insertion The point of muscle attachment that is more moveable

Isometric contraction No change in muscle length as it generates tension

Kinematics The branch of mechanics that is concerned with the description of movements

Kinetics The study of internal and external forces, energy, power and efficiency involved in the movement of a body

Manubrium The upper part of the sternum

Median	Divides the body into left and right sides via a centerline demarcation.
Medial	Refers to structures closer to the median line or towards the inside of an anatomical structure.
Negative DAP	When the foreleg of the diagonal pair touches down before the diagonal hind leg
Origin	The part of muscle attachment that is least moveable
Ossification	The process of bone formation
Overtracking	Distance between the hind limb and front limb hoof strike; it is positive if the hind limb lands in front of the front limb.
Paddling	A type of gait abnormality usually associated with a toe-in confirmation of the front limbs. The foot breaks overs the lateral toe wall and deviates outwards during flight.
Plaiting	Extreme form of paddling where the horse places one hoof – either front- or hind limb – in front of the other in a straight line.
Positive DAP	When the hind leg of the diagonal pair touches down before the diagonal foreleg
Posture	Describes how the horse organizes itself in the way it stands and moves.

Proprioception The subconscious awareness of the relative position of the body and its limbs in space, their relationship to each other and the surrounding environment.

Protraction Movement of a body part forwards

Retraction Movement of a body part backwards

Range of motion ROM The full movement potential of a joint

Rotation Twisting movement around a longitudinal axis. E.g., shaking the head; twisting the vertebrae

Sagittal plane An anatomical boundary that exists between the left and right sides of the body. The sagittal plane runs parallel to the longitudinal axis

Stance phase When a foot is in contact with the ground

Stability The resistance to a change in the body's acceleration, or the resistance to a disturbance of the body's equilibrium

Swing phase When the hoof is lifted and brought forward in a pendulum action

Suspension phase When no hooves are in contract with the ground

Sweeney A condition that affects the suprascapular nerve of the shoulder. The shoulder muscles atrophy and flatten with abnormal prominence of the shoulder joint and spine of scapula. The shoulder and limb have an outward rolling action as the horse moves

Synergy The working together of systems. i.e., nerves and muscles

Synovial fluid Lubricating fluid found in most joints with hydraulic properties

Tensor To stretch out. E.g., Tensor Fascia Latae

Thorax Region found within the chest cavity cranial to the diaphragm

Transverse plane An imaginary plane that divides the body into superior and inferior parts. It is perpendicular to the coronal plane and sagittal plane. Also referred to as axial plane

Directional terms

Caudal Towards the tail

Cranial Towards the skull

Distal Away from the point of attachment

Dorsal Towards the top line

Lateral Towards the side of the body

Medial Towards the midline of the body

Proximal Towards the point of attachment

Rostral Structures located towards the nose

Ventral Towards the underside

BIBLIOGRAPHY

Brama, P.A.J.; TeKoppele, J.M.; Bank, R.A.; et al. (2002). *Exercise and Bone development.*

Equine Veterinary Journal, 34(2), 143-149.

Brown, S., Kaiser, J. L., Stubs, N.C., Lavagino, M. (2014). Swing phase kinematics of horses trotting over poles. Equine Veterinary Journal. Vol 47:.

Deane, N.J & Davies, A.S. (1995) *The function of the equine carpal joint: A review*. The New Zealand Veterinary Journal. Vol 43:2 pp 45-47.

Geor, R. (2002). *Are your horse's bones tough enough?* College of Veterinarian Science. Michigan USA.

Gleerup, K.B., Forkman, B., Lindegaard C., Andersen, P.H. (2015). *An Equine Pain Face.*Veterinarian Anaesthesia and Analgesia. Vol 42(1) pp 103-114.

Higgins, J. & Martin, S. (2009). *How your Horse moves. A unique visual guide to improving performance*. David & Charles Limited. Newton Abbot UK.

Hinchcliff, K.W; Geor, R.J. & Kaneps, A.J. (2008). *Equine Exercise Physiology: The Science of Exercise in the Athletic Horse*. Elsevier Limited. Philadelphia USA.

Johnson,A. 2010. How to perform a complete Neurologic Examination in the Field and identify abnormalities. AAEP proceedings. Baltimore. USA.

Kawcak, C.E. (2012). *Response of equine bone to exercise*. Equine Orthopaedic Research Centre. Colorado State University. Fort Collins USA.

Kentucky Research Staff (2018). *Principles of Bone Development in Horses*. Kentucky Equine Research. Versailles USA.

Marlin, D. (2007). *The Airways and Lungs.* The horse media group LLC.

May-Davis, S. (2016). *The colourful trial of 'form versus function'*. Cessnock Australia.

May-Davis, S. (2016). *Dissecting out the 'Facts!'*. Cessnock Australia.

May-Davis, S. (2016). *The Elbow: A joint in Trouble.* Article provided for free in online portal.

Mcilwraith, C.W. (2004). *The Equine Skeleton: How does bone grow and how do abnormalities in the developmental process affect soundness?* Colorado State University, Colorado, USA.

Muir, P.J., McCarthy, C.L., Radtke, M.D., Markel, E.M., Santschi, M.C., Scollay, V.L. (2006). *Role of endochondral ossification of articular cartilage and function adaptation of the subcondral plate in the development of fatigue microcracking of joints*. Bone, Elsevier.
Volume 38, Issue 3. Pages 342-349.

Paoletti, S. *(2006)*. *The Fasciae: Anatomy, Dysfunction & Treatment*. Seattle, WA: Eastland Press. pp. 146–147.

Pilliner, S. & Davies, Z. 1996, *Equine Science Health and Performance,* Blackwell Science, Cambridge, Mass., p.7.

Sødring Elbrønd, V. & Schult, R.M. (2015). *Myofascia – The unexplored tissue: myofascial kinetic lines in horses, a model for describing locomotion using comparative dissection studies derived from human lines.* Knowledge Enterprise Incorporated. Copenhagen Denmark.

Smythe, R. H. and Goody, P. C. (1993). Horse structure and movement, 3rd edition. J. A. Allen: London.

Sullivan, H.M., Acutt, E.V., Barrett, M.F., Salman, M.D., Ellis, K.L. and King, M.R. (2022). *Influence of Chronic Lameness on Thoracolumbar Musculus Multifidus Structure in the Horse.* Journal of Equine Veterinary Science (117): 104053.

Tokuriki, M., Otsuki, R. and Kai, M. (1997). Electromyographic activity of trunk muscles duringocomotion on a treadmill. In: 5th WEVA Congress, Padova. Journal of Equine Veterinary Science Vol. 17: 488.

Rogers, M. (2010). Confirmation or posture or posture? A new perspective.

Van Weeren. P.R., McGowan, C., Haussler, K. (2010). Science overview: Development of a structural and functional understanding of the equine back. Equine Veterinary Journal. Vol. 42(38): 393-400.

Von Scheven. C.C.A. (2010). The anatomy and function of the equine thoracolumbar longisimmus dorsi muscle. Ludwig-Maximilians University Munich.