Science Of Motion®

Hind Leg

Functional Anatomy

"The proper functioning of the locomotor system depends on the precise synchronization of the movement of each part on every other part and in relation to the body as a whole." (James R. Rooney, the biomechanics of Lameness in horses)

There are numerous parts in the hind leg and the precise synchronization of the movement of each part on every other part demands a lot more than just a whip activating the hind legs.

James Rooney pointed out that for efficient locomotion, vertical movement, lifting the body against the force of gravity, should be reduced to a minimum in favor to a more horizontal movement. The kinematics of the hind limbs, as well as the front limbs are designed to minimize vertical movement.

The coffin joint is designed for a simple down and up translation. Immediately after impact, the coffin joint rotates downward during the first half of the stride and then upward.

The coffin joint is mobilized by only one muscle or more exactly the deep digital flexor tendon, which is controlled by the deep digital flexor muscle.

The attachment of the deep digital flexor tendon on the coffin bone has been the subject of a recent study showing alteration of the structure of a horse suffering from navicular syndrome by comparison to a unaffected horse.

The area where a gradual transformation of soft tissue to bone allows transmission of force between the deep digital flexor tendon and the distal sesamoid bone, is referred to as enthesis. .

There are numerous sensors in this area.

The second phalange rotates around the coffin joint. On the dorsal part of the joint formed by the first phalange and the coffin bone is the distal sesamoid or navicular bone.

The purpose of the navicular bone is ensuring that the angle of attachment of the deep digital flexor tendon with the coffin bone remains always the same.

We will come back on the navicular bone but we have to further construct the hind limb to fully understand how it works

The front part of the second phalange can be the site of arthritis. Ring bones are often developed on the lower part of the second phalange and in some instances one upper part of the coffin bone.

For many years, research studies regarded the junction between the second (PII) and first phalange (PI) as insignificant treating the first and second phalange as a single unit. James Rooney and later Dr, Hilary Clayton demonstrated that movements occurred between the two phalanges and were part of proper motion.

The junction between PI and Mt3, (canon bone), is the fetlock. There are two sesamoid bones on the palmar side, which are part of the suspensory apparatus, as well as insertion of the straight sesamoid ligament.

The sesamoids are quite large by comparison to Mt3. The reason is that they have several important functions. They are intercalated in the suspensory apparatus, serving to increase the surface area of the fetlock joint. The horse is a model of efficiency where intense forces have to be absorbed without increasing enormously the size and weight of the structure. This beautiful picture of Bessie in action demonstrates that for speed on the race track, efficiency over the jump and elegance in the dressage ring, the horse's lower legs have to be relatively light and therefore capable to withstand enormous forces without too much mass.

In their "Mechanical analysis of locomotion", Anton J. van den Bogert and his group of researchers, demonstrated that during the stance, forces were acting downward, as expected by gravity, but also upward, from the hoof capsule, the coffin joint and the fetlock up onto the limb. Forces generated by the deep digital flexor tendon resisting the dorsiflexion of the pastern around the coffin joint as well as the suspensory ligament, superficial flexor and deep digital flexor tendon together with their check ligament, are acting upward several times during the stance.

Joints such as the fetlocks, the hocks, the knees, are supported by tendons and without the presence and support of the tendons, the joints would not be capable to sustain the intensity of the acting forces. Without the assistance of the tendons and associated muscles, the joints would have to be many times bigger. By increasing the surface of the fetlock joint, the sesamoids increase the capacity of the structure to deal with forces acting on the joint.

Another task of the sesamoids is enhancing the torque force exerted by the flexors tendons against the rotation of the fetlock joint. The sesamoids displace the tendon from the center of rotation. The concept is easy to understand. When a tendon or a muscle is acting close from the axis of the joint, its action is more stabilizing. At the contrary, if a muscle or tendon is acting on an angle from the joint, the forces exerted is more a rotary force moving the bones. Dorsiflexion of the fetlock is resisted by the tendons and with the sesamoid, the torque force exerted by the tendon increases.

Another feature of the sesamoids is providing a constant angle of the suspensory apparatus and flexor tendons relative to the fetlock joint. As the fetlock translates downward, the angle of the suspensory apparatus and flexors tendons does not change. Without the sesamoids bones, the dorsiflexion of the fetlock would induce accelerated tensions on the ligaments and tendons and consequent failures.

The surface area of the deep digital flexor tendon passing over the palmar surface of the sesamoids is wider allowing to spread the forces acting on the tendon over a greater area. The superficial flexor tendon also has a sleeve bearing area over the sesamoids.

During the first half of the stride, the down translation of the fetlock involves the rotation of PII around the coffin bone (PIII) and the rotation of Mt3 around PI. The down translation of the fetlock is referred to as dorsiflexion. When the fetlock translates downward and therefore PI rotates around the coffin joint, the distal end of PI moves downward and consequently, without the resistance of the distal sesamoid ligament as well as the attachment of the superficial flexor tendon, the articular surface of PII would theoretically move in the opposite direction and therefore upward. The distal sesamoid straight ligament tightens resisting the upward movement of PII around PI.

At impact and during the first half of the stride, the lower attachment of the superficial flexor tendon also stabilizes the junction between the first and second phalange.

The superficial flexor tendon has two attachments. The distal attachment is on PI and is therefore resists the downward translation of the fetlock. The proximal attachment is on PII resists both, pastern dorsiflexion and fetlock dorsiflexion.

The hind legs carry less weight and when the hind leg impacts close from the line of action of the center of gravity, the successive tightening of tendons and ligaments is slightly different than for the forelegs. Suspensory damages of the forelegs are often related to increased weight while damages of the suspensory ligaments of the rear legs result more often from kinematics abnormality. James Rooney explained that abnormal movements of small tarsal bones composing the hock could displace the lateral splint bone, Mt4, creating stress on the suspensory ligament.

A close look at the mechanism explains how increased tension can occur altering the integrity of the structure. When the pastern translates downward and the canon bone rotates forward, there is a screw like twisting movement that further tightens the extensor branches of the suspensory ligament. We are only at the second joint of our hind leg construction and the point consistently emphasized by the science of motion is already underlined. Two factors have to be considered concurrently. One is proper balance and functioning of the hoof structure allowing efficient management of the forces loading the hoof. This is the task of the farrier. The other factor is the direction, duration, intensity and frequency of the forces loading the limbs. This is the rider task. Only an equitation educating and coordinating properly the muscular system of the thoracolumbar column that is ensuring correct weight distribution and limbs kinematics, can allow the horse to benefit of correct hoof balance.

Improper hoof balance can exaggerate or counteracts the twisting motion of the fetlock during dorsiflexion. As well, a horse traveling with a thoracolumbar spine laterally bend to the right for instance, coupled with an inverted rotation, will increase the intensity of the load on the left fetlock and also the direction of the force and consequently has the potential of altering correct dorsi and palmar rotations of the fetlock as well as the screw like motion.

At impact, when the fetlock translates downward, the suspensory ligament tightens first followed by the superficial flexor and the deep digital flexor tendon.

The main resistance to the down translation of the fetlock at impact is the system composed of the suspensory ligament, superficial flexor and deep digital flexor tendon together with their check ligament. The three act as elastic element absorbing energy that will be used for the following upward rotation of the fetlock. They also support and guide the lower limb in its normal range of movement. The deep fascia enveloping both flexor tendons blind them together reinforcing their action.

The deep digital flexor tendon, which is attached on the back of the coffin bone opposes strong resistance to the downward translation of the fetlock.

As the fetlock translates upward, the angle between the pastern and the canon bone opens in what is referred as palmar flexion. During the second half of the stride, the suspensory shortens first rotating the coffin joint. The superficial flexor tendon tightens then causing pastern and fetlock rotation. The deep digital flexor tendon tightens then causing fetlock rotation.

When the fetlock rotates downward more than its normal range of motion, such as for instance on older horses with straight hocks, suspensory ligament and superficial flexor tendons are under greater stress.

While on a two-dimensional view, the fetlock translates downward and upward, there is, on a three-dimensional view, an inward rotation coupled with the dorsiflexion and palmar flexion. The lower end of Mt3 is the fetlock. The upper end is the hock. Therefore, the twist occurring within the fetlock during the inward and upward rotation, is going to induce an inward rotation of the lower joints composing the hock.

During the stride, there is an inward rotation of the tarsal bones of the fetlock that is precisely synchronized with the flexion and extension of the joint. When flexion and extension of the joints are altered due to morphological flaw such as straight hocks or sickle hocks, off synchronization between flexion, extension and inward rotations cause sharing forces or friction between the joints and the development of arthritis. As well, riding and training techniques causing functional straight or sickle hocks are damaging the hock joints.

Advanced research studies are only useful if they are applied. Understanding in details equine locomotion allows preventing injuries by distinguishing riding and training techniques respecting the integrity and function of the structures from riding and training techniques making a dysfunctional horse altering proper function of the fetlock, hock and higher joints.

The problem of lunging for instance is that the horse body leans at an angle of approximately 69˚. The body inclination alters proper down and up translation of the fetlock creating abnormal synchronization between the different components of the fetlock as well as hock structures. This is one of the reason why we have created a lunging technique minimizing the stresses slowing down the horse cadence and working in straight lines as often as in circle. This is also one of the reasons why we never use any round pen.

Mt3, which is often referred to as the “cannon bone”, does have two small splint bones on the back part. The outside one, (lateral), is Mt4 and the inside one, (medial), is Mt2. While relatively common on the forelegs, rear legs splints are uncommon and almost invariably on the lateral side. At impact the beginning of the stance, forces are applied rotating T3 laterally and driving T4 against the head of Mt4. Mt4 is then submitted to a downward as well as rotary force from T4. The other splint bone, Mt2 is only submitted to a downward force. Mt4 as well as Mt2 are covered by the suspensory ligament and James Rooney theorized that kinematics abnormalities of the hock and therefore abnormal forces on Mt4 could cause suspensory damage.

We often warn against the practice of creating artificial limbs gesture touching the hind legs with a whip. The problem is that making the lower part of the leg move without adequate synchronization of the movements of the upper part of the limb, creates asynchroneous movements of the components of the joints and consequent injuries. The amplitude of the limbs movements is for a great part, the recoil of an elastic strain energy stored in the tendons, aponeurosis and even muscles during the first half of the stride. Beauty and efficiency of the limbs movements are the outcome of precise coordination between vertebral column mechanism and limbs action. When such subtle coordination is not achieved with adequate training, gimmicks are use imitating the limbs action With a whip or other probe, but at the cost of the joints' integrity.

This is the difference between biomechanics and pathomechanics. Biomechanics is educating and coordinating vertebral column mechanism and limbs movements, as they are designed to functions. Instead, pathomechanics is teaching the move without understanding how the horse physique effectively functions and therefore, exposing bones and other structures to pathological changes and consequent injuries. Biomechanics is about upgrading old beliefs to new knowledge. Pathomechanics, is about integrating new knowledge to old beliefs.

The hock is a joint composed of several tarsal bones designed to precisely combine flexions, extensions and inward rotations. When inward rotations are not properly synchronized with flexion and extension of the joint, frictions occur inducing damages on the cartilages. Bog spavin for instance is often due to asynchronous movement of the relevant bones of the tarsus. The development of shearing forces between the joint surfaces may be expected when the forces exerted on the joints are maximal. On the rear leg, forces exerted by and on the leg are maximal at the end of the stride, just before the hoof leaves the ground.

Most hock problems are related to conformation and the nature of the work. Injecting the hocks might provide transient relief, but injecting the hocks without correcting the thoracolumbar dysfunction inducing abnormal limbs kinematics and consequent sharing forces or frictions on the joint, does not fix the problem. A close look at the movements occurring in the hock during locomotion, allows preventing asynchroneous movements and consequent injury.

In terms of the hock, like for every other structure, preventing injury is more efficient than repairing injury. Repairing injuries is often recreating function but rarely as efficient function than prior the injury. In many instances, the integrity of the structure is damaged for life. Therapies promise full recovery but truly, the structure rarely recover full integrity. The main teaching of the science of motion is preventing injury.

In most instances kinematics abnormalities inducing static or sliding frictions on the joint, originate from dysfunction of the thoracolumbar spine. Identifying and correcting the thoracolumbar dysfunctions protect the joint from aberrant friction or torsion causing pathological changes and consequent injuries. This dramatic hind limb kinematics abnormality, induced aberrant stresses on the hock joint. It was corrected addressing the back muscles imbalance. An area situated on the right side of the thoracolumbar spine was the root cause of the limb torsion. It was not possible to fully correct the problem but as you can see in this video, correcting the back muscle imbalance greatly reduced the torsion of the left hock.

Before the hoof contacts the ground, the tibia has, by extension of the stifle rotated around the long axis of the bone, from medial to lateral.

At impact, the tibia and the tibiotarsal bone, (TT) is stationary. The tibiotarsal bone, TT, and the central tarsal bone, (TC), are also stationary.

Under the impact force, a slight flexion of the hock and stifle may occur rotating TT and TC back toward the medial side.

Simultaneously, dorsi-flexion of the fetlock causes a lateral rotation of Mt3 that is turning around its long axis. Mt3 and T3 rotate then laterally.

We have at this instant, Mt3 and T3 rotating laterally while TC and TT are held stationary or rotating slightly medially.

This precise orchestration of flexion and inward rotations provides maximum contact of one joint surface and therefore maximum stability and capacity of weight bearing. James Rooney refers to this position as close packed or synartrotic position. This orchestration pertains until the second half of the stride.

During the second half of the stride, the hind limb produces maximum propulsive force. The tibia, and therefore TT and TC rotate medially. Simultaneously, the pastern elevates inducing a medial rotation of Mt3 and T3. The hock moves away from its close packed position, and the hoof leaves the ground.

Conformation defects, as well as kinematics abnormalities can alter proper synchronization of the tarsal bones. Kinematics abnormalities related to sickle hocks, keeps Mt3 and T3 stationary in their lateral rotation instead of moving medially as they should. The abnormality induces shearing force between TC and T3. TC would rotate medially while T3 and Mt3 would remain stationary. It would be a sliding friction between TC and T3 and a static friction between T3 and Mt3. Static frictions are greater than sliding friction and therefore, the static friction occurring between Mt3 and T3 would slow and restrict the rotation of T3 creating abnormal friction between T3 and TC. This is why, arthrosis between T3 and TC is often observed in horses with sickle hocks.

There are also functional and dynamics equivalent altering proper rotations of the tarsal bones. Based on the old and false belief that the alighting hind leg propels the horse's body upward as soon as ground contact, authors and artists, place the horses' hind legs in an advanced position under the belly that would indeed, cause arthrosis between T3 and TC. This statue illustrates the classical concept of the hind legs engaged under the horse's body. The sculpture fit a fantasy but is contradicted by reality. Beside the fact that the horse would not be capable to stand and move in such posture, the horse would develop severe arthrosis between T3 and TC.

As well, classical theories promote similar misconceptions. Classical literature presents this silhouette as an adaptation of the horse hind legs to advanced training. Such adaptation would create functional sickle hooks exposing the horse to the same pathological damages than morphological sickle hocks. The picture of the fused hock previously presented would apply to this drawing. Applying classical literatures without upgrading the wisdom of our ancestors to actual understanding of equine biomechanics, exposes the horses' hocks to arthritis.

This piaff for instance, is a classical piaff. The alighting hind leg touches the ground under the vertical of the tuber coxal. The hind leg could alight a little more forward. Many classical illustration show alighting of the hind legs even less forward. Wanting the hind leg more forward under the belly is a misconception based on literature but ignoring biomechanics. The misconception forces the horse into aberrant kinematics of the hind legs. Instead of acting as a spring, which is the normal functioning of the hind legs at the trot, the hind limbs have to function as a lever inducing abnormal stresses on the joints.

In a comparative study, between world class athletes, that Holmstrom defines as "good movers," and school horses, that the Swedish scientist defines as "poor movers", one of the main difference was the dorso-ventral rotation of the pelvis coupled with the forward swing of the hind limb. The forward motion of the limb is coupled with a dorso-ventral rotation of the pelvis, while the backward movement, is coupled with a ventro-dorsal rotation of the pelvis. The pendular movements of the hind leg and the dorso-ventral rotation of the pelvis are proportional but always moving in the same direction. Dorso-ventral when the hind limb moves forward and ventro-dorsa when the limb move backward. Holmstrom shows different position of the hind limb at middle of the stance, during working trot, collected trot, passage and piaff. There is always a dorso-ventral rotation of the pelvis proper to the limb position. When by accident or questionable training techniques, the pelvis and the hind limb move in opposite direction, the sacroiliac joint is exposed to damage. The lunging techniques placing a strap behind the hind legs to create, “greater engagement”, place at the end pf the stride, when the hind legs moves backward during the propulsive phase, a situation where the backward movement of the limb is restricted by the strap while the pelvis continue to rotate ventro-dorsally. Repeated over and over, the abnormality exposes the sacroiliac joint to injury.

Proper dorso-ventral rotation of the pelvis is related to sound functioning of the thoracolumbar column. When the motion of the thoracolumbar spine is restricted by training errors such as rushing the horse faster than its natural cadence, back muscles stiffen restricting thoracolumbar spine movements. As a result, the lumbar vertebrae flatten inducing flattening of the pelvis sacrum unit. A common adaptation of the hind legs to restricted rotation of the pelvis, is early impact of the alighting hind limb. The lower part of the hind leg is then too far back in relation to the upper half of the hind limb. The situation creates another type of shearing forces on the tarsal joint creating shearing forces between T3 and Mt3. Arthrosis between T3 and Mt3 is often observed on horses with straight hocks. The situation describes above creates a similar problem that can be defined as “functional straight hock”.

At the other end of the tibia is the stifle joint. The phenomenon known as upward fixation of the patella occurs when the stifle over-extends closing and angle of 145˚. The angle of impact is about 135˚. Under normal circumstances, the stifle is incompletely extended at impact. If extension of the stifle is carried beyond roughly 143-145˚, the tibia undergoes a final lateral to medial rotation. The final lateral to medial rotation of the tibia rolls the medial patelar ligament over the medial ridge of the femoral throchlea, which is the locking mechanism of the stifle.

From improper hoof balance to dysfunction of the thoracolumbar spine, there are numerous abnormalities that can induce abnormal stresses on the stifle. A common reason is when the horse is asked for greater engagement of the hind legs without adequate dorso-ventral rotation of the pelvis.

Jean Luc Cornille