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The influence of side reins on symptoms of supporting limb lameness in horses

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Für meine Eltern, Großeltern und meine Schwester für die unglaubliche Unterstützung auf meinem Weg, Tierärztin zu werden.

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1. Introduction:

Lameness due to pain in the limbs is the most frequent reason why a horse is taken to a veterinarian (Kaneene et al. 1997, Putnam et al. 2014), and the main reason why horses are excluded from competitions (Nagy et al. 2014). It therefore has a great economic impact on equestrian sports and horse husbandry in general (Anon. 2001). Recognizing the lameness and locating its origin plays an important role in the daily routine of equine veterinary practitioners. For the horses, the detection of lameness symptoms is also a welfare issue (McGowan and Ireland 2016). On the one hand missing early symptoms of lameness can worsen the prognosis if the horse has an orthopedic problem (Baxter 2011), so it is desirable to recognize them as soon as possible. On the other hand, lameness usually leads to a loss of value of the horse (Barrett and Arkins 2020), and on competitions no symptoms of lameness are allowed to be seen (Fédération Equestre Internationale 01.01.2020). The correct or false interpretation of the indicating symptoms does not only affect the medical treatment of entrusted patients, but is also essential for identifying lame horses at competitions or purchase investigations (Barrett and Arkins 2020).

The sensation of pain in a limb while bearing weight leads to the characteristic movement pattern of supporting limb lameness in horses. With semi-quantitative scoring the intensity of the lameness is usually graded in degrees according to subjective visual evaluation by the veterinarian. The main criterion for this is the asymmetry in the vertical movement of the head and the croup (region of the pelvis) of the horse. Commonly in fore limb lameness this asymmetry is described as “head nod” or “the horse is falling on a leg” (Baxter and Stashak 2011, Lischer and Rheinfeld 2018). The correct evaluation of these symptoms can be difficult in mild cases, especially in hind limb lameness or for unexperienced observers (Peham et al. 2001, Marqués et al. 2014, Hammarberg et al. 2016, Starke and Oosterlinck 2019). Therefore, it is worth investigating, whether different circumstances could possibly have an impact on these symptoms and lead to a disguise or enhancement of them. As the vertical movement asymmetry of the head is the major symptom of forelimb and a symptom of compensatory hind limb lameness (Lischer and Rheinfeld 2018), restriction of the head movement could hypothetically be one influencing factor. The horse’s head position can be manipulated by different external influences or fixation methods, as it is as usually part of horse riding (Miesner 2007). Mostly, manipulation is done with the rider’s reins or auxiliary reins. The methods and the amount of confinement differ between the different sport disciplines. This study focuses on side reins, which are common auxiliary reins and are recommended by the Fédération Équestre Nationale of Germany (FN) (Miesner 2007). They are not allowed in competitions except for vaulting (Fédération Equestre Internationale 01.01.2020). Before horses start training under a rider, they are usually started in ground work like lunging. For this, side reins are commonly used. Therefore, young horses are exceedingly often or exclusively trained with side reins. More groups of horses, that are equipped with side reins a lot, are vaulting horses and school horses for the training of beginner riders (Miesner 2007). These horses spend a lot of time in this confined position and their trainer observes them mostly like this. Particularly for young horses the detection of lameness symptoms is outstandingly important, as they usually are trained very intensely and have their biggest increase of value at the start of a possible sports carrier (Preston et al. 2008).

The aim of this study was to show, if the use of side reins could influence the motion pattern of supporting limb lameness: Especially, the vertical movement asymmetry of head, trunk and pelvis. Does the veterinarian need to consider side reins as disturbing factor for a correct diagnosis? Besides this main hypothesis, the data of the kinematic analysis allow further comparisons of lameness between different gaits or different marker placements (Head and withers/trunk).

- Hypothesis 1: The vertical movement asymmetries, measured at the head and trunk marker, differ in supporting limb lame horses.
- Hypothesis 2: The vertical movement asymmetry differs between walk and trot in supporting limb lame horses.
- Hypothesis 3: Side reins have an effect on the vertical movement asymmetries of head and trunk in supporting limb lame horses.
- Hypothesis 4: Side reins have an effect on the vertical movement asymmetry of the croup in supporting limb lame horses.
- Hypothesis 5: The vertical movement asymmetry of head, trunk and croup differs, if the supporting limb lame horse is bended to the left or the right through asymmetric long side reins in trot.

2. Literature survey

2.1 Relevant functional anatomy of the locomotor system of the horse

Horses gained much popularity as domestic animals because of their excellent locomotor system (McNeill 2013). They respond with flight when threatened, so they are made to move forward very efficiently (Miesner 2007). Simultaneously they have to carry the weight of their large bodies and their heavy gastrointestinal tract. As form follows function, these requirements to the statics and dynamics of the horse are reflected in its anatomic construction. The different parts of the horse's body create a well-coordinated and complex unity, working together to ensure a fluent and efficient movement (Maierl et al. 2019).

In movement, the hind limbs with the big muscles of the croup provide most of the forward impulse. The forelimbs support about 56 % of the horse's body weight and while moving they allow a fluent transfer of the forward directed energy originated in the hind limbs (Maierl et al. 2019). The trunk with the spine as fundamental structure has its role in locomotion in connecting the fore- and hind limbs, being an origin for many muscles, and also contributing to a fluent movement actively and passively with own muscles, tendons, ligaments and joints. The neck and head, as more eccentric masses to the point of balance of the horse, also show characteristic movement patterns during the gait in elongation to the trunk (Wolschrijn et al. 2013). The neck for example works as lever arm for the heavy head, which can be utilized by the horse to shift weight during movement (Loscher et al. 2016).

While the forelimbs are attached to the trunk only by muscles, a so called *synsarcosis*, building a suspension apparatus for the trunk in between both forelimbs, the hind limbs are connected to the spine through the *articulatio (art.) sacroiliaca*. The muscles of the limbs can be divided into muscles between trunk and limb, and in muscles with origin and insertion only on the limb itself. Through the shoulder and pectoral girdle muscles the limbs can be moved relatively to the body in the suspension phase, while in the stance phase they transfer the forces from the ground to the trunk and move the body forward. With the muscles originating and inserting only on the limb itself the exact movement of the joints and the positioning of the limb is provided. Generally, in the limbs the masses of the muscles are located proximally, while in the distal parts of the limb there are mostly passive parts of the movement apparatus like tendons and ligaments. As horses stand and move most time of the day and lay down rarely, they have a complex system of these passively working structures to save energy (Fig. 1, Maierl et al. 2019). After active positioning of the limbs by muscle force, in the impact and stance phase the passive parts of the locomotor system receive energy by being stretched and loaded. Like this they store energy and release it after the mid-stance into the push off phase (Gellman and Bertram 2002). Further the construction of the horse's joints makes the limbs move predominantly in the sagittal plane. Only small ranges of movement in other planes in some joints are possible (Clayton and Back 2013, Liebich and König 2019).

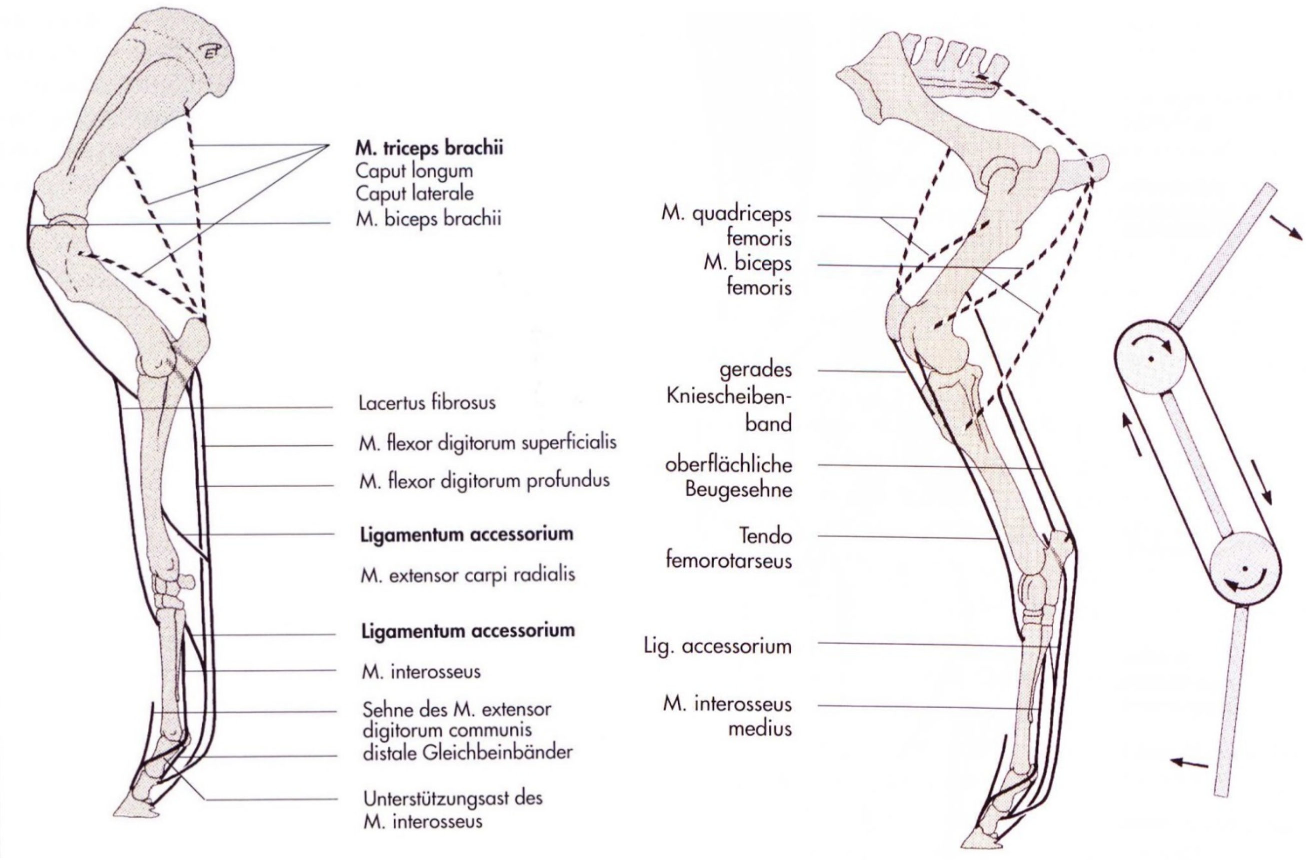

Fig. 1: Schema of the passive movement apparatus of the forelimb (left) and the hind limb (right) of the horse (Maierl et al. 2019)

Along the spine, neck and chest there are many muscles and passive structures to adapt the movement for a fluent locomotion. With the principles of symmetry and metamerism, many of them are organized in segments. Examples are *the mm. longissimi*, *mm. rotatores* or *mm. intertransversarii*. Those and many more can move the spine and trunk vertically, laterally and rotationally. As the neck and head have a greater range of movement in comparison to the trunk, there are many additional muscles to move them individually. The passive structures of the locomotor system along the spine are also outstandingly pronounced (Gellman and Bertram 2002). Most important for transferring vertical energy between head, neck and trunk are the *ligamentum (lig.) nuchae* and the *lig. supraspinale* (Liebich et al. 2019, Denoix and Pailloux 2001) (Fig.2).

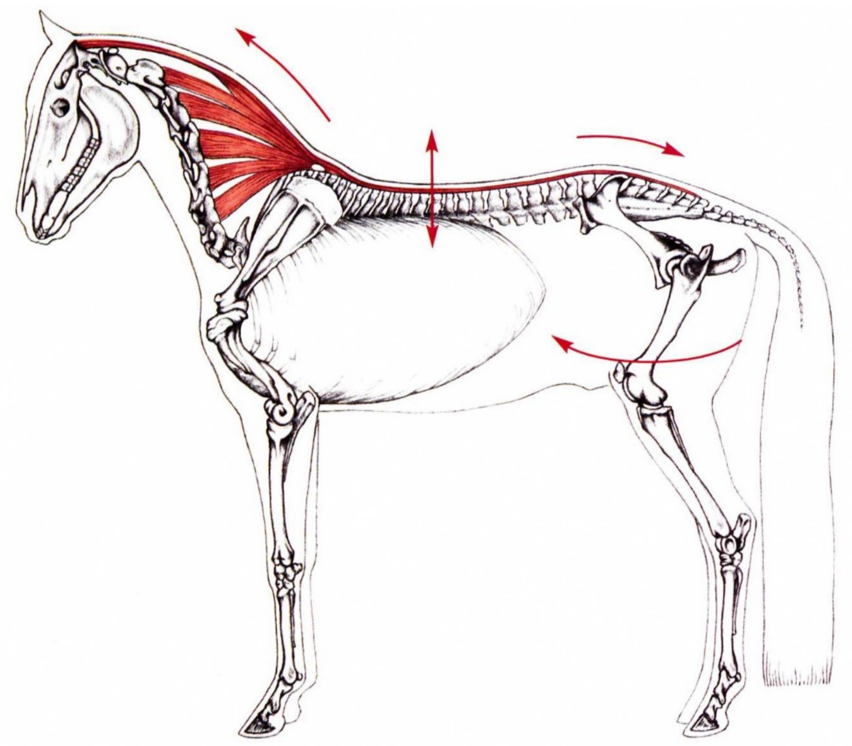

Fig. 2: *Lig. nuchae* and *lig. supraspinale* (both red) connect different parts of the spine and influence the biomechanics of attached structures (Heuschmann 2015).

The *lig. nuchae* can be divided into *funiculus nuchae* (insertion at *squama occipitalis*) and *lamina nuchae* (insertions at the *processus spinosi* of the *cervical vertebrae 2-6 (C2-C6)*). It is continued as *lig. supraspinale* and so connects the head and cervical spine with *the processus spinosi* of the thoracic spine, lumbar spine and the *os sacrum*. The position of head and neck influences the tension on these passive structures and therefore the position of the back, and vice versa. Through the firm *articulationes sacroiliacae* the alignment of the *os sacrum* influences the alignment of the *ossa coxae*, what also effects the big muscles originating in this region. So each movement adaption along the spine has an effect to the different parts of the spine with its related structures and therefore the gait of the horse (Heuschmann 2015). Examples for different head and neck positions and their influence on the spine and hind limbs can be seen in Fig. 3 A-C.

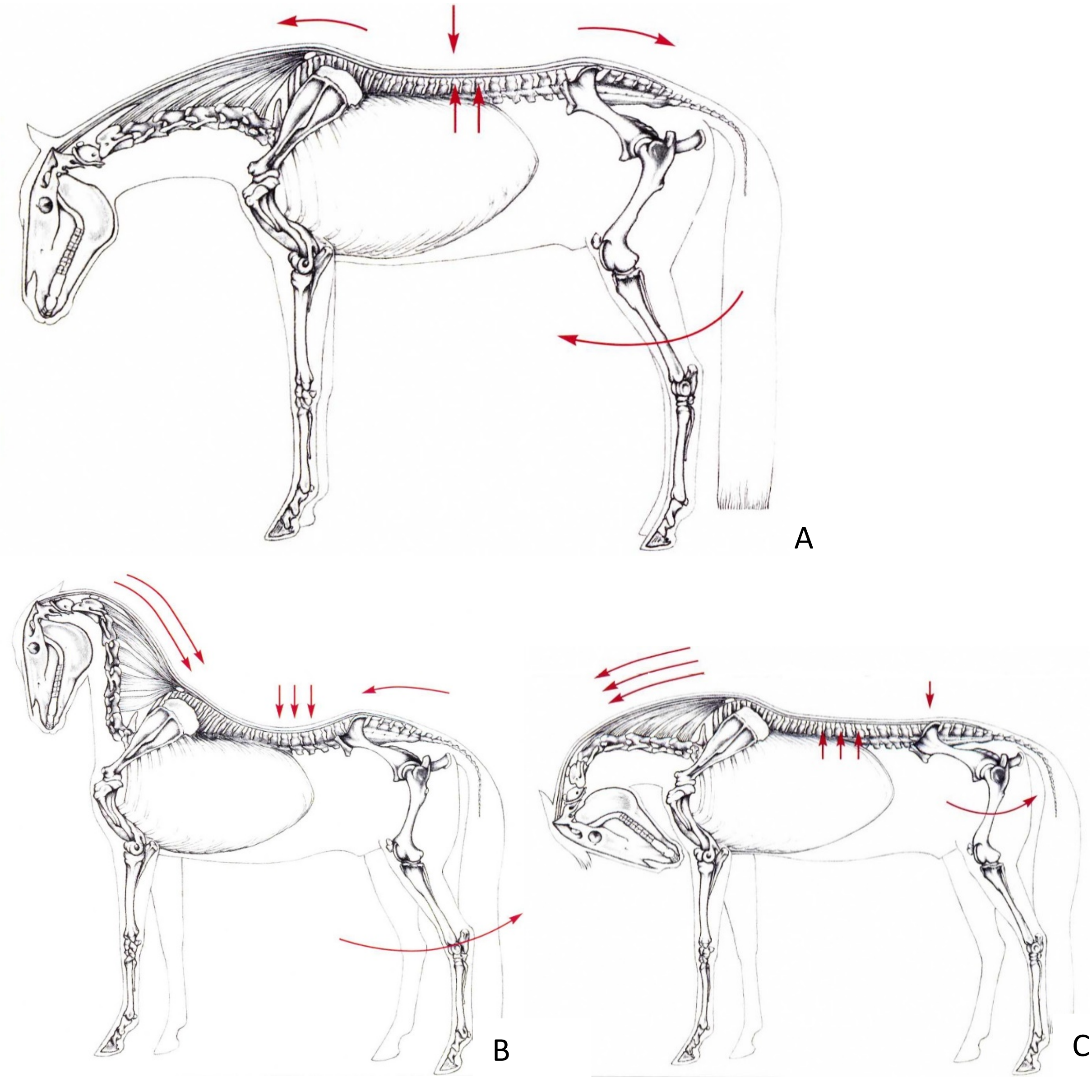

Fig. 3: Influence of different head and neck positions on the spine and attached structures (Heuschmann 2015).

A relative, but not overly firm or loose tension along these structures allows a fluent, flexible and controlled movement of the head, neck and back. The hind limbs can step further under the horse's body and support weight efficiently (Fig. 2, Fig. 3A, Heuschmann 2015). If the relative tension in these structures is disturbed (Figg. 3B, 3C), the mobility along the spine and in the hind limbs is restricted (Heuschmann 2015, Rhodin et al. 2009, Rhodin et al. 2005, Stodulka 2006).

2.2 Dynamics of the sound horse

Each gait of the horse consists of a periodically repeating movement pattern. One complete sequence of this pattern is called a movement cycle. At the end of each cycle another follows in the same way and including movements in the whole body, they form the typical gait impression of the horse (Barrey 2013).

As the horse uses the limbs alternately, each limb has a phase of stance and a suspension phase. The stance phase consists of an impact, mid-stance and a push-off phase (Keegan 2016). The rhythmic footing alternation causes weight shifts between contralateral and ipsilateral limbs (Clayton and Schamhardt 2013). Characteristic footing patterns of different gaits not only lead to different types of forward movement, but also to different vertical, lateral bending and rotating forces in the horse's body during movement (Buchner 2013).

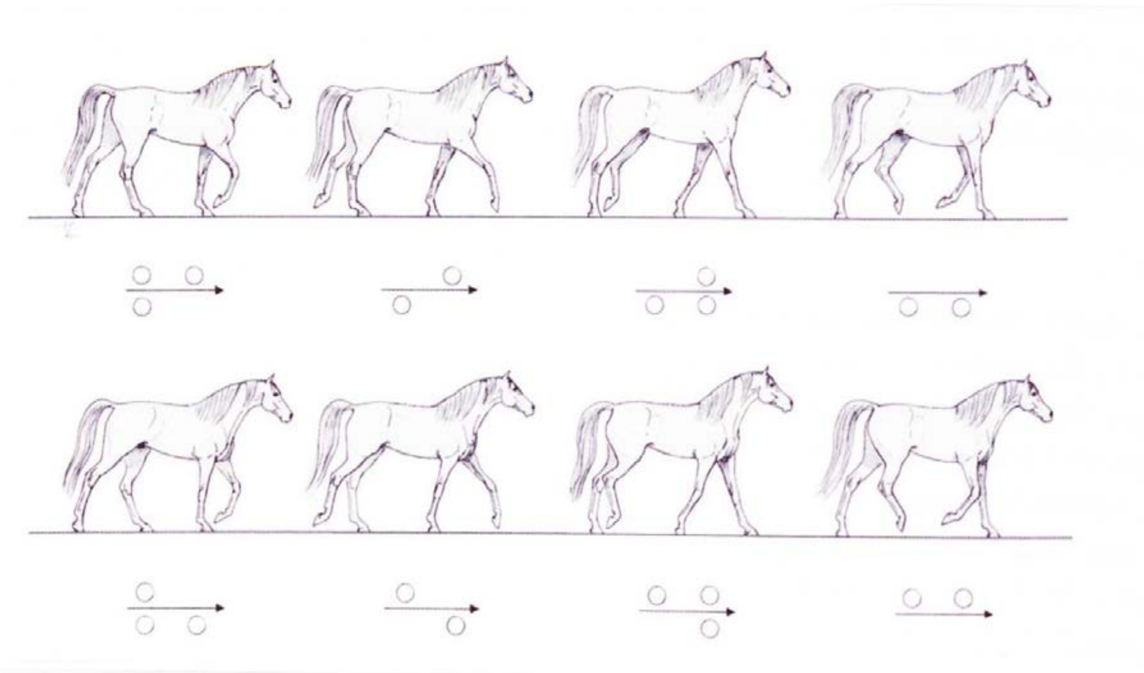

Fig. 4: Movement and footing pattern of the horse in walk (Lischer and Rheinfeld 2018)

In this study the horses have been observed in walk and trot. Both gaits have symmetric movement patterns unlike canter, and are therefore more useful and better understood for detecting asymmetry in the gait due to lameness (Lopes et al. 2016). The walk of the horse has a four-beat rhythm with eight phases of footing (Fig. 4), while trot is a gait in a two-beat rhythm with four phases of footing (Fig. 5) (Hildebrand 1965). Every movement cycle consists of two parts with the same, but time-delayed movement of the left and right half of the body. The trot is specially characterized as a zestful gait with diagonal footing pattern and a phase of general suspension of the horse (Barrey 2013).

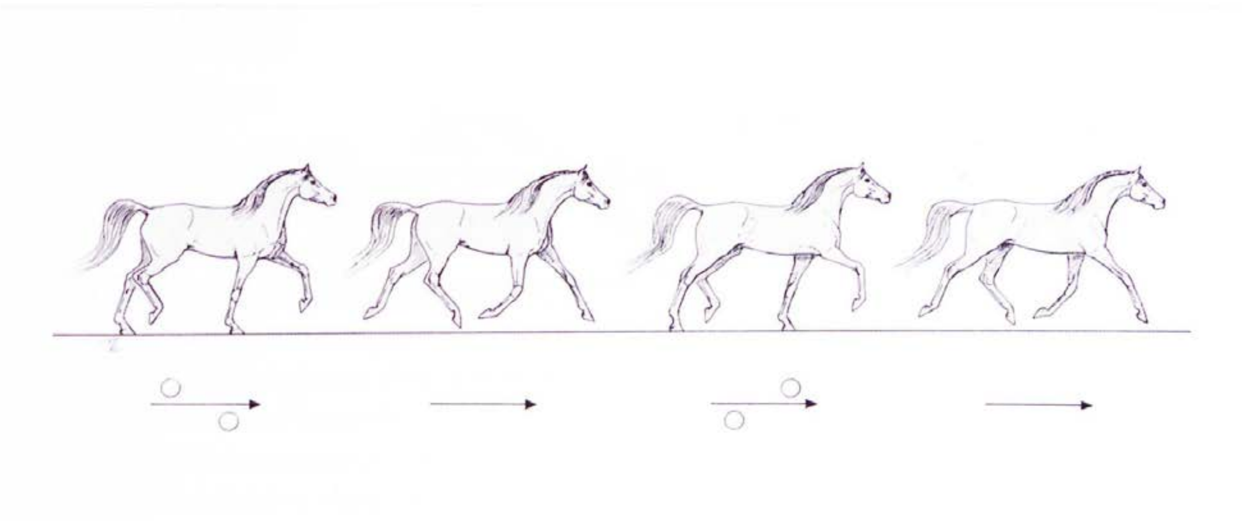

Fig. 5: Movement and footing pattern of the horse in trot (Lischer and Rheinfeld 2018).

As already mentioned, the gait does not only consist of limb movement. It is rather a summation of every periodically repeating movement in the whole body during locomotion. In the impact and mid-stance phase of a hind limb, the leg starts bending and carrying weight (Barrey 2013). The croup is lowered in this moment. During the push-off phase the limb is straightened, creating a forward-upward-impulse, so the croup of the horse is lifted. Same repeats in the other hind leg, so during one movement cycle the croup of the horse is lowered and lifted twice (Fig. 6) (Lischer and Rheinfeld 2018). The rotation of the croup during movement (Buchner et al. 1993) is not analyzed in this study and further not described.

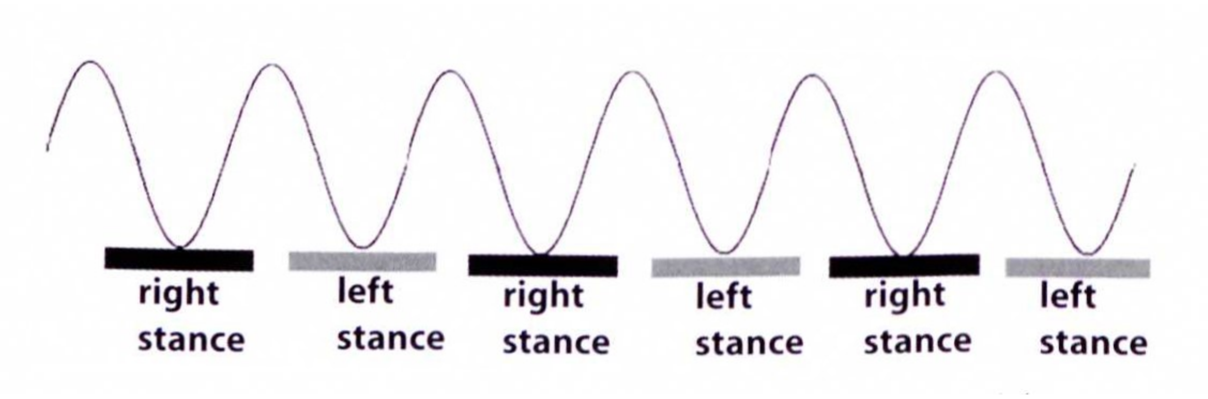

Fig. 6: Symmetrical lowering and lifting of head, trunk and croup during movement, this can be described as sinusoidal curve. (Keegan 2011)

Similar things happen in the forehand. During cyclic load redistribution of both forelimbs the chest between the limbs is moved vertically, too. So during a movement cycle it is lifted and lowered twice (Fig. 6) (Buchner, H. H. et al. 1996). This is easy to measure or observe on the withers (Rhodin et al. 2018).

For load redistribution the horse uses vertical head and neck movement efficiently to save energy in locomotion (Loscher et al. 2016). From the impact to the mid-stance phase of a forelimb, head and neck are lowered and increase the limb's load. In the push-off phase head and neck are lifted, what helps to decrease the limbs load before suspension. As the contralateral limb impacts the ground then, head and neck movement repeats symmetrical to complete the movement cycle. So head and neck move parallel to the trunk between the forelimbs, but even in a greater range (Keegan 2011, Ross and Dyson 2011).

As horses are borne with a slight asymmetry in their body conformation (Miesner 2007) the described movements are almost, but not perfectly symmetric in both halves of the movement cycle (Byström et al. 2018, Pfau et al. 2018, Rhodin et al. 2017, van Weeren et al. 2018). The approximate threshold to distinguish between sound and lame horses is a vertical movement asymmetry difference of 6 mm at the head for forelimb lameness, and 3 mm at the croup for hind limb lameness (Keegan 2011).

2.3 Dynamics of the lame horse

When a horse suffers pain in a limb during locomotion, it adapts its movement to avoid or lower the sensation of pain (Lischer and Rheinfeld 2018). This is described as lameness and can be seen in the loss of symmetry of the gait. We can divide lame movement patterns into two groups of symptoms with different reasons. The symptoms of supporting limb lameness occur when the horse is suffering pain during the stance phase of the affected limb. Supporting limb lameness can be more specified into impact, mid-stance and push off lameness, but most cases are a mix (Keegan 2016). When the horse is suffering pain during the suspension phase of the limb, this leads to different symptoms like e.g. shortening of the stride (Lischer and Rheinfeld 2018). As this study deals with supporting limb lameness, only these symptoms are described.

When suffering pain while stepping on a hind limb, the horse avoids loading the affected limb and distributes more weight to the contralateral hind limb during the movement cycle (Kramer et al. 2004). Therefore, in a painful impact and mid-stance phase, the croup is not lowered as much as it is in the sound limb. If the push-off is painful, the croup is not getting the same upward impulse and therefore the croup is not lifted to the normal height. In most (mixed) cases we therefore see a greater lowering, followed by a greater push-off with higher lifting of the croup in the sound stance phase and a smaller lowering, followed by a smaller push-off in the lame limb (Fig. 7). Depending on which parts of the stance phase are painful, the symmetric sinusoidal curve of the vertical croup movement becomes characteristically asymmetric due to different effects of the minima and maxima of the sinusoidal curve (Keegan 2011). A similar pattern, parallel to the croup movement, can also be observed at the withers in hind limb lameness (Rhodin et al. 2018).

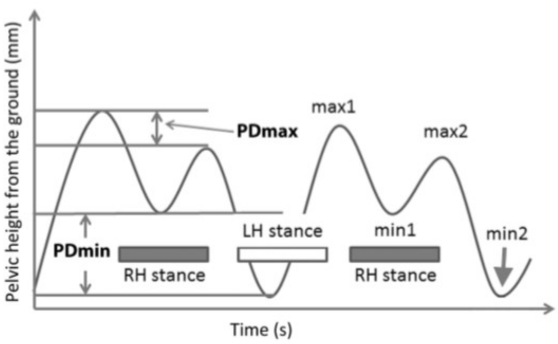

Fig. 7. Asymmetric vertical movement of the croup in an example of right hind limb lameness (Bell et al. 2016). PD = pelvic height difference, RH = right hind limb, LH = left hind limb, max = maximum, min = minimum, s = seconds

In forelimb lameness similar things occur. The symptoms can be seen in the vertical movement of the chest, but also amplified in vertical head and neck movement (Keegan 2011, Ross and Dyson 2011). While stepping on the painful limb the chest, neck and head are not lowered as much and are less firmly pushed off in comparison to the stance phase of the sound limb. This causes an asymmetric sinusoidal vertical movement in these parts, too (Fig. 8).

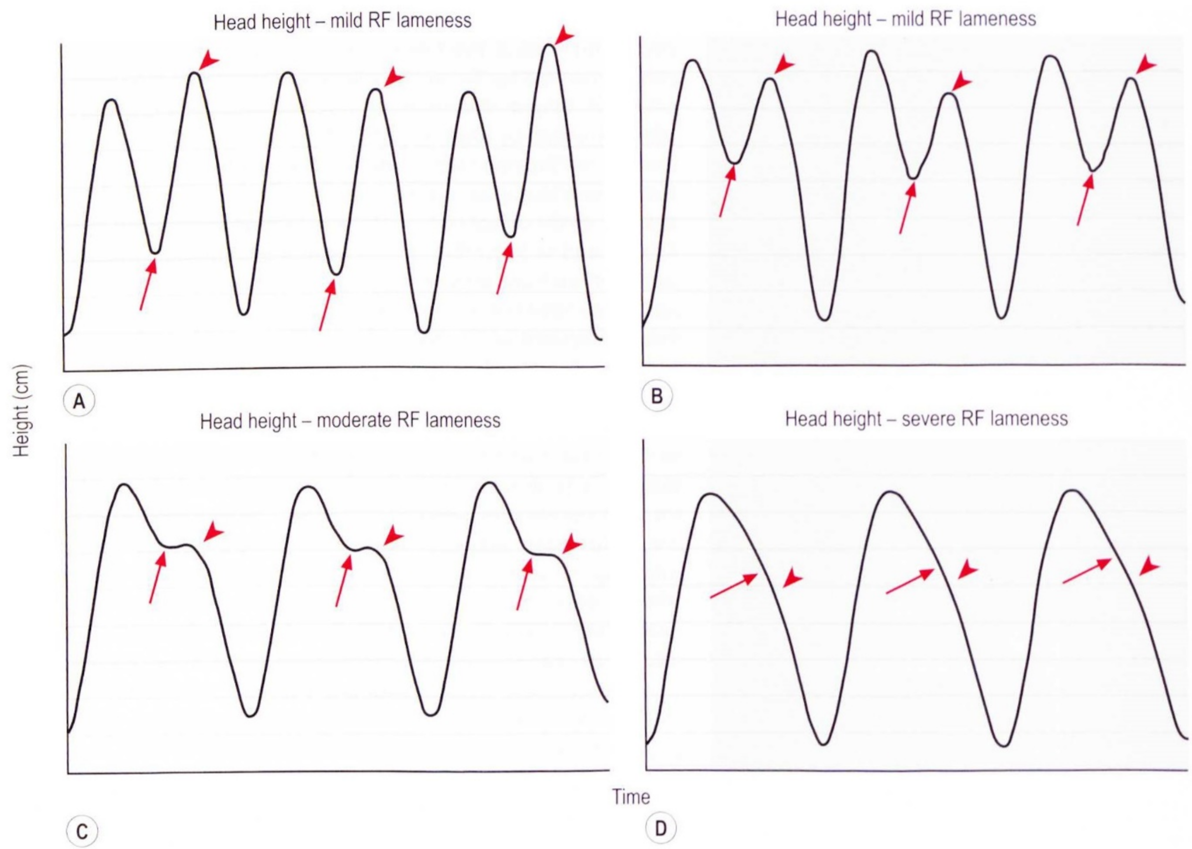

Fig. 8: Different degrees of vertical movement asymmetry in horses with different severities of right forelimb lameness (Kaneps et al. 2014). RF = right forelimb. Severity of the lameness increases from A to D.

But in many cases the redistribution of load happens not only in between contralateral limbs, but also from a painful hind limb to the front and from a painful front limb to the hind parts of the horse’s body. For example, in trot, when the right hind limb stance is painful and the diagonal left front limb is in stance phase at the same time, the horse shifts weight to the left front limb to lower the load on the left hind limb. This is achieved by lowering head and neck what could be misinterpreted as right front limb lameness (Lischer and Rheinfeld 2018). Therefore, in hind limb lameness an ipsilateral compensatory forelimb lameness happens. The Rhodin et al. 2018 study has shown, that in this cases the vertical trunk movement, measured at the withers, still moves parallel to the real lame movement pattern of the croup. It is lowered when the sound hind limb is in stance phase and not when head and neck are lowered in the stance phase of the painful limb. So the trunk movement can be used to distinguish between a real additional lameness in the front limbs, or a compensatory lameness due to pain in a hind limb.

When a horse is lame in a front limb, unlike the compensation mechanisms of the hind limbs, a “diagonal compensation” happens. In the stance phase of the sound forelimb, also the diagonal hind limb is more loaded and the croup is lowered. This can be misinterpreted as lameness of the diagonal hind limb (Lischer and Rheinfeld 2018). In these cases, the trunk movement also behaves like the real forelimb lameness and is lowered simultaneously to head and neck (Rhodin et al. 2018).

Other symptoms of supporting limb lameness, such as varying joint angles (Buchner et al. 1996), stride durations (Buchner, Salvenberg et al. 1995) or ground forces (Merkens and Schamhardt 1988) are not evaluated in this study. In bilateral lameness also complicated patterns can occur (Buchner, Savelberg et al. 1995), which have not been considered in this study.

2.4 Principles of lameness examinations in horses

To identify the concerned limb and the cause of lameness, a veterinarian has to consider the motion analysis in context to other procedures of the orthopedic examination (Lischer and Rheinfeld 2018). In the beginning, the anamnesis and the description of the horse is requested. Then the horse is observed in square standing for its conformation, visible abnormalities or asymmetries of the locomotor system and possible postures of load relief. In addition, contraindications for a motion analysis are ruled out in advance, such as suspicion of fractures and fissures, where too much movement could have fatal consequences. Before or after the motion analysis (Baxter and Stashak 2011) a superficial and a deep, specific palpation of the limbs and other parts of the locomotor system, especially neck and back, are performed. In many cases, this helps to localize and characterize a problem and plan further diagnostic procedures.

Usually the motion analysis in the veterinary examination is done by observation with the human eye. First, the horse is observed in walk, then in trot. Considered are the footing and placement of hooves, the movement of the limb in the suspension phase and the symmetry/asymmetry of the gait (signs of lameness). To assess hind limb lameness, the horse is directed away from the examiner, who stands exactly behind the horse. It is most common to evaluate the vertical movement asymmetry of the croup in the middle of the pelvis, and the rotation asymmetry of the pelvis. When the horse is moving towards the examiner, it is judged for fore limb lameness. Main criterion is the vertical movement asymmetry of the head, the “head nod”. After this procedure in walk and trot the horse is observed from the side to specify this information and look for symptoms of suspension phase lameness. A semi-quantitative grading, for example degree 0 – 5 (American Association of Equine Practitioners) is used to assess the lameness after specific attributes of severity. To specify the characteristics of the lameness additional procedures can help. The horse can be moved on a soft or hard ground, backwards, in big or small circles or 8-figures, or it is lunged in different gaits including canter and the transitions between the gaits. In some cases, it can help to present the horse under the rider, too (Greve and Dyson 2013a, 2013b, Swanson 2011).

In mild lameness or complex cases with more than one affected limb, additional procedures may help to identify the affected limb or limbs. Such can be provocation tests like flexing specific joints or letting the horse stand on an angular wedge before motion analysis. Their purpose is to amplify the pain in specific structures, what does not only help to identify the affected limb, but also to specify the origin of pain in the limb itself. In trot, immediately after one of these procedures, an increased asymmetry is visible in a positive test. Another strategy is to reduce pain in regions of the limb by diagnostic anesthesia of nerves or joints. After injection of the local anesthetic, a reduction in the movement asymmetry can be observed if the painful region is in the anesthetized (Lischer and Rheinfeld 2018).

When the limb and affected region are identified, further diagnostic procedures, like diagnostic imaging, are used to find the cause of the lameness and the underlying pathology.

Rarely instead of visual motion analysis technical methods are used to evaluate the lameness objectively. Some sensor based systems are available and are applicable for veterinary practitioners. Examples are the Lameness Locator® (Equinosis, Columbia, USA), EQUIGAIT® (Equigait Ltd, UK) or EquuSense (Equusys Inc., Cambridge, USA). They work with accelerometers and/or gyroscopes, placed on head and croup, or additional at withers and *tubera coxae* of the horse, to measure the vertical movement asymmetry. However, they are not widely spread in the daily routine of veterinaries. Their application and interpretation needs more time in comparison to the visual motion analysis and for most practitioners this does not surpass the benefits (Keegan et al. 2004). Other objective measuring methods like kinetic or kinematic motion analysis on a treadmill are not applicable for the daily routine, too, but are used for scientific research (Keegan 2011, Ross and Dyson 2011).

2.5 Principles of horse training and the use of side reins

Generally, there exists a multitude of horse sport disciplines with diverse training methods and desired movements and postures of the horse. In some disciplines, like the so called English disciplines, a specific head and neck position due to the above described biomechanical mechanisms is desired (Fédération Equestre Internationale 01.01.2020). It is fundamental for dressage, and a basic training in dressage is the background for other disciplines like show jumping, eventing, vaulting or driving (Miesner 2007).

Depending on breed and targeted discipline, young horses are started in training under the rider with three to four years on average (Miesner 2007). Prior to this, the horse is usually started in groundwork, where the horse is doing exercises directed by a trainer from the ground. Like this, the horse can get comfortable in the daily routine with humans and its locomotor system can adjust to exercise first without additional weight of the rider (Ohmura et al. 2013, Rieskamp 2011). A very popular ground exercise is lunging, where the horse moves on a circle around the trainer (Miesner et al. 2011). The lunge connects the halter or the snaffle bit of the horse with the hand of the trainer. Auxiliary reins like side reins are used to achieve the required head and neck position (Fig. 9), what in ridden horses is achieved by the rider's hands. Auxiliary reins are attached between a breast belt/saddle and the bit in the horse's mouth in different ways.

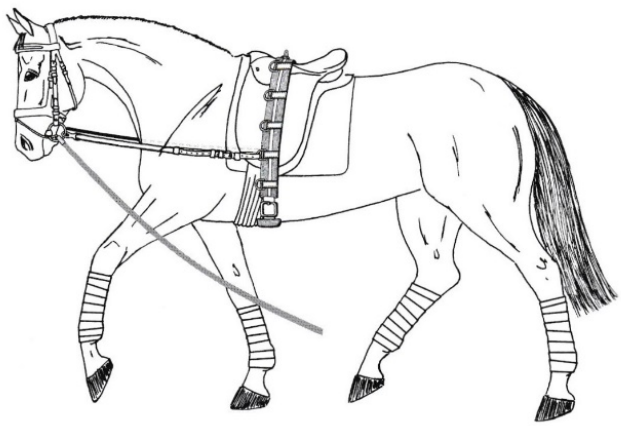

Fig. 9: Horse equipped with side reins on the lunge, head and neck position "on the bit" according to FN (Miesner et al. 2011).

The aimed posture grants a soft and steady connection between the rider's hands and the bridle and its purpose is to bring the horse in a balanced position for training, without losing its relaxation (Miesner 2007). In the dressage rules of the (Fédération Equestre Internationale 01.01.2020) it is described as follows: "A horse is said to be "on the bit" when its head is more or less raised and arched according to the stage of training and the extension or collection of the pace, accepting the bridle with a light and consistent soft submissive contact. The head should remain in a steady position, as a rule slightly in front of a vertical, with a supple poll as the highest point of the neck, and no resistance should be offered to the Athlete." The position "on the bit" should be sought by the horse and be provided by the rider's reins or accessory reins. Accessory reins like side reins are not only used during lunging, but also for unexperienced riders to achieve a better understanding of the aimed training posture by giving the horse the opportunity to be "on the bit", independent from the riders abilities (Miesner 2007). In disciplines unrelated to dressage like racing, western disciplines, gaited horse disciplines or endurance there are different training principles and due to different postures of the horse, accessory reins like side reins only play a minor or no role. Also in classical dressage, simple side reins are seen controversially (Stodulka 2006). With side reins the horse is able to move its head vertically up and down on a circle line, where the attachment point of the side reins to the breast belt is the center of the circle and the length of the side reins is the radius. Stretching of the neck forward-downwards, what is desired especially in young horses, is not possible (Miesner 2007). If the side reins are adjusted too short, the breathing can be disabled and wrong muscles are build up pronounced. In these cases, the horses are not able to move with a swinging and relaxed back and negative consequences for the movement ranges and health of the horse occur (Stodulka 2006).

Most side reins are made of leather, but also cord or synthetic materials can be used (Miesner et al. 2011). They can be with or without elastic elements, while elastic elements absorb force peaks (Clayton et al. 2011). Usually they are connected to the bit with a carbine. Around the breast- or saddle belt, the end of the rein is closed to a loop with adjustable length. The useful length is adjusted after the upper mentioned criteria and depends of the size, aimed posture, kind of training and anatomic conformation of the horse (Miesner 2007). Both side reins are adjusted in the same length, even when a horse is moving on a circle while lunging (Stodulka 2006). The effect of side reins can also be varied by attaching them in different heights on the horse's chest. Recommended is the height of the shoulder joint (Miesner 2007).

2.6. Principles of kinematic motion analysis of horses

While the human eye is a great instrument for motion analysis, interpretation carries the risk of subjectivity (Clayton and Schamhardt 2013, Keegan 2011). The repeatability in scoring lameness can be good when it is done by an experienced clinician, but there is considerable variation between different clinicians and inter-rater agreement can be poor for mild lameness, especially in the hind limbs (Hewetson et al. 2006, Keegan et al. 1998, Keegan et al. 2010, Peham et al. 2001). To analyze the movement of the horse objectively for scientific research, a kinematic or similar accurate analysis is advisable (Keegan 2011). On a treadmill neutral circumstances for a kinematic analysis are given (Seeherman 1991). The kinematic analysis generally measures the geometry of movement and allows to relate the movement of different parts of the body to each other (Clayton and Schamhardt 2013). In comparison to the semi-quantitative scoring by the veterinarian, it is a quantitative method. By videography, the accurate position of different points of interest in the horse's body can be measured. For this, markers are attached to these points to the skin and cameras around the horse capture their location. The markers need to provide a sufficient contrast from their background, therefore mostly they are reflective. In some regions of the horse's body a relevant skin displacement towards the underlying structures must be considered, what can be more than 12 cm in the proximal limb regions (Schamhardt 1996). Distal to elbow and stifle joint skin displacement is small enough to be neglected.

One camera is able to gain two-dimensional position data of the markers. For a three-dimensional reconstruction, each marker must be visible for at least two cameras during the analysis. Then software combines the data of several cameras. Each position data consists of longitudinal, vertical and horizontal information in relation to the horse's body. To achieve information in necessary detail, a high-speed camera with a rate of minimum 120 frames/s should be used. The higher the frequency of the recordings, the more detailed is the information (time resolution) (Clayton and Schamhardt 2013).

For the setup, first the reflective markers need to be attached to the horse. Then it is brought to the treadmill. Fixed positions of the cameras around the treadmill allow a calibration to the position of the horse, what must be done before the recording. If the horse is moving in a different angle than calibrated, mistakes in the analysis occur. After measurement, the collected data were digitized and then transformed to integrate the digitized coordinates into the calibrated information. By direct linear transformation, the two-dimensional views are combined to a three-dimensional view. The next step is to smooth the data that normally has high-frequency noise. During the horse's movement also random asymmetric events like stumbling or looking around nervously occur. Smoothing is usually done by a digital filter followed by finite difference- or curve-fitting technique. For a sufficient kinematic analysis an amount of not disturbed movement cycles is needed, what after (Fredricson et al. 1980) can be already 3-5 strides. Finally, the data has to be normalized in certain parameters (e.g. duration of the movement cycle, stride length) to make a comparison between different movement cycles or horses possible. The data from the kinematic analysis are temporal (e.g. stride duration), linear (e.g. stride length) and angular (e.g. velocities, acceleration) (Clayton and Schamhardt 2013).

3. Material and methods

The data have been collected in the study of the master thesis of Potz 2016. Material and methods of this kinematic motion analysis were described in Kau et al. 2020. Only differences to this study are specified below.

Both referred studies have been approved by the ethic commission of the University of Veterinary Medicine Vienna under the protocol numbers 29/04/07/2014 (Potz 2016) and 10/05/97/2012 (Kau 2020).

3.1 The horses

Fifteen adult and lame horses of different breeds and genders have been involved. Thirteen are owned by the University of Veterinary Medicine Vienna and two horses have been provided by private owners. Description of used horses (breed, age, gender and usage) are shown in Table 1. The reasons for supporting limb lameness are manifold in the horses and not in all cases finally diagnosed.

Table 1: Data of the horses. (VUW = University of Veterinary Medicine Vienna)

	Breed	Sex	Age (years)	Usage
Horse 1	Trotter	Gelding	27	Experimental animal of the VUW
Horse 2	Warmblood	Gelding	26	Experimental animal of the VUW
Horse 3	Trotter	Mare	17	Experimental animal of the VUW
Horse 4	Trotter	Gelding	16	Experimental animal of the VUW
Horse 5	Hungarian warmblood	Gelding	16	Leisure horse
Horse 6	Warmblood	Gelding	26	Experimental animal of the VUW
Horse 7	Trotter	Mare	16	Experimental animal of the VUW
Horse 8	Haflinger	Mare	15	Experimental animal of the VUW
Horse 9	Haflinger	Mare	17	Experimental animal of the VUW
Horse 10	Austrian Warmblood	Gelding	13	Dressage horse, L class

Horse 11	Noriker	Gelding	5	Leisure horse
Horse 12	Warmblood	Gelding	27	Experimental animal of the VUW
Horse 13	Warmblood	Mare	19	Experimental animal of the VUW
Horse 14	Trotter	Mare	12	Experimental animal of the VUW
Horse 15	Trotter	Gelding	13	Experimental animal of the VUW

The gender distribution of mares to geldings is 40 % to 60 %. The average age is 17.6 ± 6.4 years.

3.2 The equipment

All horses wore the same leather snaffle with a cavesson noseband (Fig. 10). An example for a marker-equippend horse can be seen in Figg. 11 and 12.

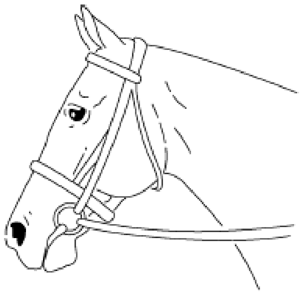

Fig. 10: Cavesson Noseband (Fédération Equestre Internationale 2020)

Fig. 10: One horse equipped with snaffle, halter, reflective markers and electrodes (latter not relevant for this study). (Potz 2016)

Fig. 11: Arrow pointing on the reflective marker located over TH12. Potz 2016, modified.

Many markers have been used in the setup of Potz 2016. Following markers have been analyzed for this study:

- Forehead
- Nose
- Side wall of all four hooves
- Croup: median over *os sacrum*
- Trunk: median over *thoracic vertebra number 12* (TH12)

For the vertical head movement, the forehead marker has been analyzed. In one horse a systemic measurement error at the forehead marker occurred, so the nose marker was analyzed to determine which forelimb is the lame one.

3.3 The test procedure

Eleven horses have been familiar with moving on the treadmill before. The unexperienced four horses have been equipped with snaffle, bit and security belt and have been familiarized with the treadmill in walk and trot until they moved fluently in both gaits and the transitions (Fig. 13).

Fig. 13: One horse is familiarized with the treadmill and the surroundings in the laboratory for movement analysis at the University of Veterinary Medicine Vienna (Potz 2016).

First, each horse has been moved without side reins in walk and trot. In each gait three measuring trials, consisting of 7-15 movement cycles each, have been performed, and repeated with side reins. .

In seven horses, additional measurements were taken at the trot, in which the side reins were set asymmetrically long. Thus, the horses were bent laterally to the left or to the right in the neck while continuing to move straight onto the treadmill. This was intended to provide additional data for the Potz 2016 study. The data were nevertheless kinematically evaluated in this study.

3.4 Data collection and analysis

To identify the lame limb(s) in each horse, the free moving (no side reins) data set in trot has been used. For forelimb lameness, the mean vertical movement of the forehead marker of one recording episode was plotted over the duration of a movement cycle. Further, the vertical motion of one hoof during the same movement cycle was used (in the same time interval). By analyzing the minima and maxima of the mean vertical head movement, combining the information with the stance phase of one forelimb, the lame forelimb was identified. For hind limb lameness, the vertical movement of the croup marker has been used in the same way and was synchronized to the stance phase of one hind limb. In cases of mixed or potential compensatory lameness, the vertical movement of the trunk has been analyzed additionally to differentiate these cases (Rhodin et al. 2018). If movement cycles contained obvious measurement errors or exceptional single events, they were excluded manually. In a case of systemic measurement error in free trot in a horse, the data of trot with side reins have been used to figure out the lame limb.

The asymmetry of the gait was determined by averaging the asymmetry of all available movement cycles in each test mode. Measurement series with errors have been excluded. To calculate the asymmetry like Peham et al. 1996, the curves have been divided into different superposed frequencies by Fourier analysis (Fig. 14). Irregular movements and single movement events appear in the Fourier spectrum as additional frequency and therefore can easily be eliminated.

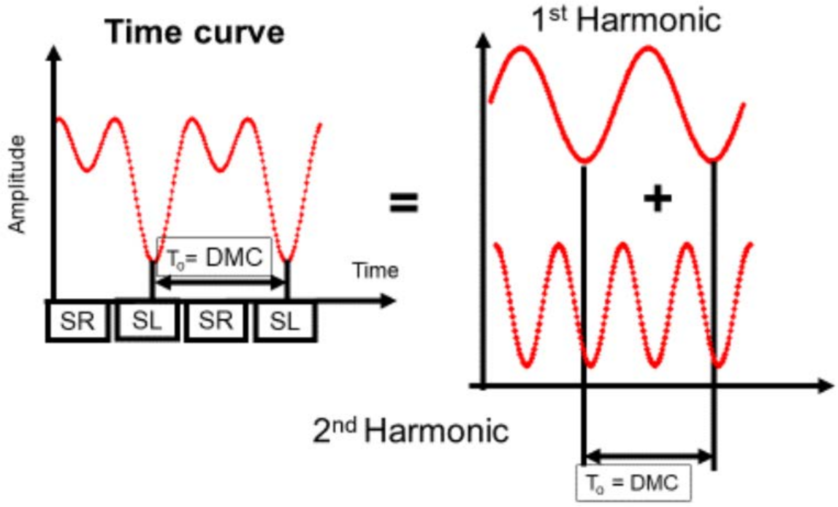

Fig. 14: Time curve of vertical asymmetrical movement before (left) and after (right) Fourier Analysis (Peham 1995). SR = Right stance phase, SL = left stance phase, DMC = Duration of a movement cycle

By setting the amplitudes of the two main frequencies, the fundamental wave ("asymmetric impact") in the normal frequency of head nodding and the first harmonic wave ("sound wave") in relation, the asymmetry is calculated with the formula of Peham et al. 1996 (Formula 1).

$$\text{SYMMETRY}[\%] = \frac{\text{AFHW}}{\text{AFW} + \text{AFHW}} 100$$

AFW = amplitude of the fundamental wave

AFHW = amplitude of the first harmonic wave.

Formula 1: Calculation of vertical movement asymmetry (Peham et al. 1996).

Table 2: Relation of vertical movement asymmetries to degrees of lameness (Peham et al. 1995).

Asymmetry of the gait in %	Degree of lameness
0-19	0
20-34	1
35-49	2A (mild peculiarity)
50-69	2B (moderate peculiarity)
70-89	2C (severe peculiarity)
90-100	3

For grading the lameness, the system of (Peham et al. 1995) was used, relating the degrees of lameness to percentages of asymmetry (Table 2).

3.5 Statistics

Statistical analysis was performed with the software SPSS (IBM®, Armonk, New York, USA). Following groups of measurement modi were formed to compare the vertical movement asymmetry of head, withers and croup with each other using student's t-test:

- Walk free (no side reins)
- Walk side reins
- Trot free
- Trot side reins
- Trot with shorter side rein on the left
- Trot with shorter side rein on the right

Normal distribution was checked with the Kolmogorov-Smirnov-test. Subsequently ANOVA with measurement repetition was performed for comparing the mean values of asymmetry of each horse and measurement modus. The level of significance was set to 5 %.

4. Results

All horses showed characteristic gait patterns of at least one lame limb. The affected limbs, degrees of lameness and distribution of the lameness degrees are shown in Table 3 and Fig. 16. Unfortunately, some data of specific markers got lost or had measurement errors, so that comparable markers were used for the analysis or the data were excluded from the study. The amount of available data is shown in Table 4.

Table 3: Vertical movement asymmetries, degrees of lameness and affected limbs of each horse in trot without side reins. As. F = vertical movement asymmetry of the head in %, D = degree of lameness after Peham et al. 1995, TH12 = Movement pattern to which the TH12 movement behaves parallel to (indicating real or compensatory lameness after Rhodin et al. 2018), As. H = Vertical movement asymmetry of the croup in %, c. = compensatory, s. = sound, *Due to measurement error of the trot data, the data of walk without side reins is shown, **Due to measurement error of the free trot data, the data of trot with side reins is shown, (P) = horse pacing instead of trotting.

	As. F	D	Lame forelimb	TH12	As. H	D	Lame hind limb
Horse 1 (P)	42.04	2A	right	both	70.59	2C	left
Horse 2	51.74**	2B	right, left c.	croup	19.22**	s.	left
Horse 3	56.06	2B	left, right c.	both	34.21	1	both
Horse 4	50.73	2B	left	head	37.04	2A	right
Horse 5	48.13	2A	right	head	15.00	s.	right
Horse 6	47.52	2A	left, c. component	croup	14.41	s.	left
Horse 7	61.50	2B	right	both	48.55	2A	left
Horse 8	47.50	2A	right	head	26.73	1	left
Horse 9	54.41*	2B	right	both	18.26	s.	right
Horse 10	36.53	2A	left	head	18.62	s.	right
Horse 11	49.85	2A	right, left c.	croup	19.31	s.	left
Horse 12	41.05	2A	right	both	16.54	s.	left
Horse 13	57.85	2B	right	croup	16.13	s.	right
Horse 14	53.38	2B	left	both	38.69	2A	both
Horse 15	60.18	2B	right	head	14.56	s.	both

The average speed of the treadmill in walk was 5.08 (± 0,77) km/h, while in trot it was 10.99 (± 2,37) km/h (Fig 15). In the forelimb, most horses lame in degree 2B with an average vertical movement asymmetry of 50.18 (± 7,09) % in free trot. In the hind limbs, most horses were sound. The average vertical movement asymmetry in free trot was 27.76 (± 16,05) %, therefore 1st degree lame.

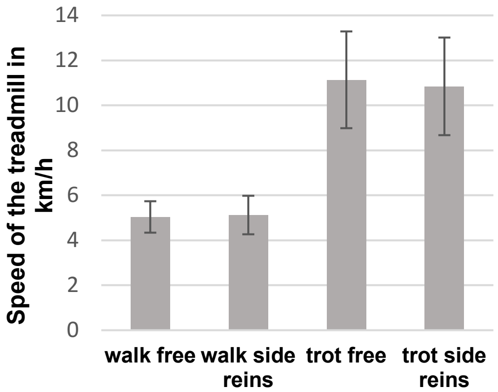

Fig. 1512: Speed of the treadmill in the different measurement modi. The data of trot with side reins include also data with asymmetric side reins.

Table 4: Quantity (n) of available movement cycles for each measurement modus and location.

	n Forehead	n TH12	n Pelvis
Walk free	239	253	240
Walk side reins	266	295	290
Trot free	332	416	404
Trot side reins	408	465	455
Trot asymmetric side reins, left short	92	104	104
Trot asymmetric side reins, right short	75	96	96

The data of the head, TH12 and croup are normally distributed, except the data in walk with side reins and trot without side reins. The normal distribution was tested with the Kolmogorov-Smirnov-test. Under the circumstance of the high number of analyzed movement cycles this doesn't need to be relevant (Lumley et al. 2002).

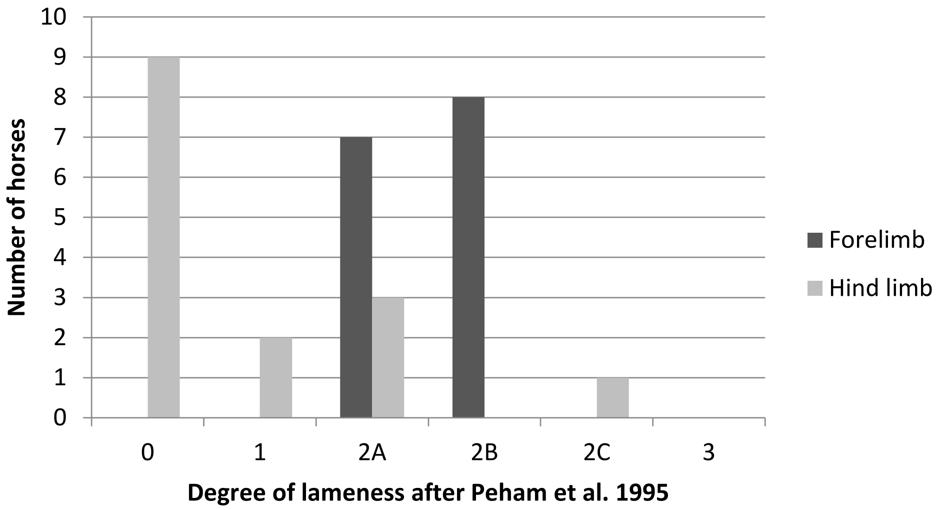

Fig. 16: Distribution of lameness degrees in the 15 horses of the study.

4.1 Hypothesis 1: The vertical movement asymmetries, measured at the head and trunk marker, differ in supporting limb lame horses.

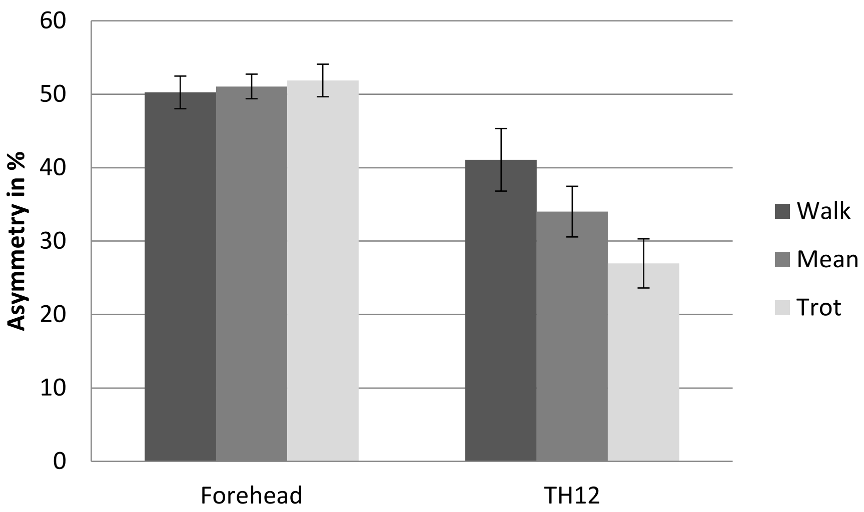

Fig. 17: Mean vertical movement asymmetry of forehead and TH12, including data with and without side reins.

In the overall comparison, independent of gait and head position (free or with side reins), at the forehead and the TH12 marker significantly different vertical movement asymmetries with a difference of 17.05 % ($p = 0.00$) have been measured (Fig. 17). While the mean asymmetry of the forehead movement is 51.06 %, the asymmetry measured at TH12 is 34.01 %. Observing only trot, this is even more obvious with a difference of 24.92 % (51.78 % at the forehead and 26.96 % at TH12). Walk shows an asymmetry difference of 9.18 % (50.25 % at the forehead, 41.07 % at TH12).

4.2 Hypothesis 2: The vertical movement asymmetry differs between walk and trot in supporting limb lame horses.

The data (Fig. 18) show a significant difference in the vertical movement asymmetry between walk and trot for the TH12 marker (walk: 41.07 %, trot 26.96 %, difference of 14.11 %, $p = 0.01$). For the vertical forehead (walk: 50.25 %, trot 51.87 %, difference of 1.63 %) and pelvis (walk: 27.80 %, trot 28.93 %, difference of 1.13 %) movement there was no significant asymmetry difference.

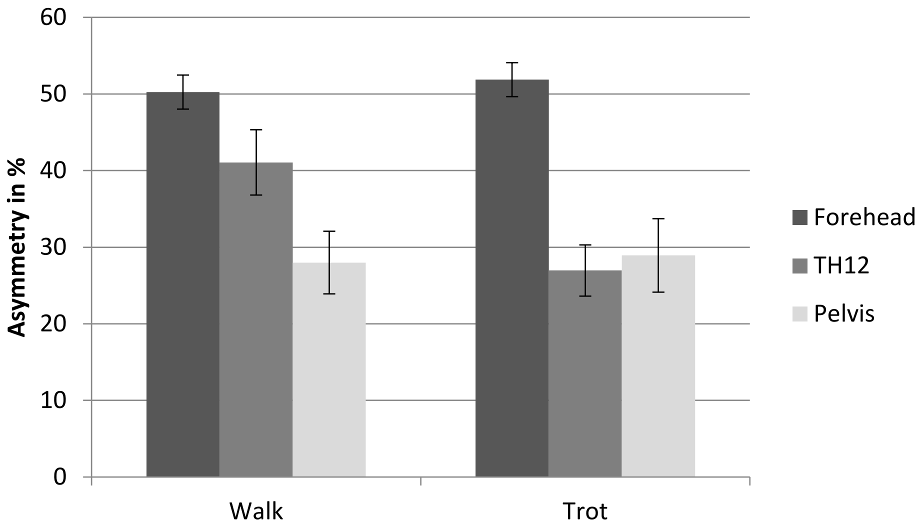

Fig. 18: Mean vertical movement asymmetries in walk and trot (data with and without side reins included).

4.3 Hypothesis 3: Side reins have an effect on the vertical movement asymmetries of head and trunk in supporting limb lame horses.

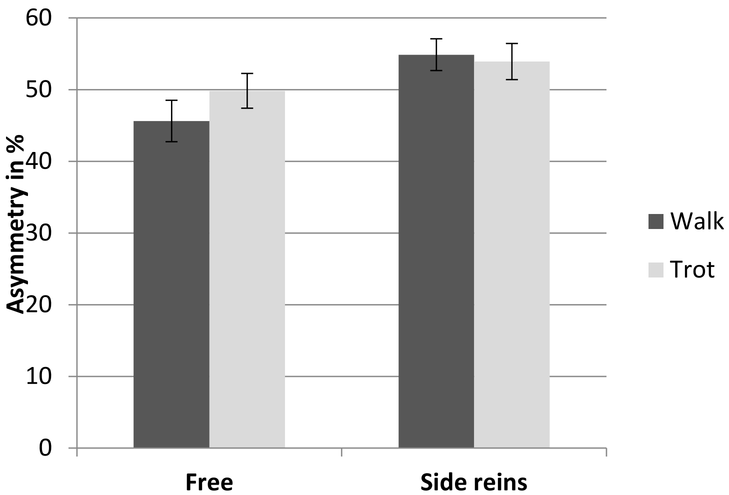

Fig. 19: Mean vertical movement asymmetries of the head marker in free moving horses and horses equipped with side reins.

In walk there is a significant difference in the vertical movement asymmetry of the forehead between free moving horses and horses equipped with side rein (p = 0,013). This does not apply to the trot (Fig. 19). In walk the asymmetry increases by 9.25 % (free: 45.62 %, side reins: 54.87 %) if the horse is equipped with side reins. In trot there is only a non-significant difference of 4.08 % (free: 49.83 %, side reins: 53.91 %).

For the vertical movement asymmetry of the trunk (Fig. 20) no significant influence of side reins is apparent, neither in walk (free: 40.96 %, side reins: 41.17 %, difference: 0.19 %) nor in trot (free: 26.75 %, side reins: 27.16 %, difference: 0.41 %).

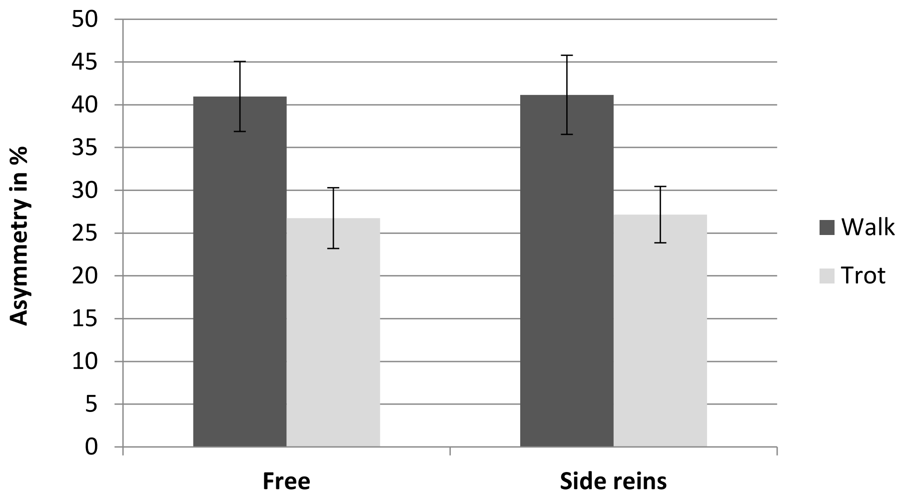

Fig. 20: Mean vertical movement asymmetry of the TH12 marker of free moving horses and horses equipped with side reins.

4.4 Hypothesis 4: Side reins have an effect on the vertical movement asymmetry of the croup in supporting limb lame horses.

The use of side reins causes no significant influence on the vertical pelvis movement asymmetry, neither in walk (free: 28.30 %, side reins: 27.69 %, difference: 0.61 % asymmetry), nor in trot (free: 27.89 %, side reins: 29.87 %, difference: 1.89 % asymmetry) (Fig. 21).

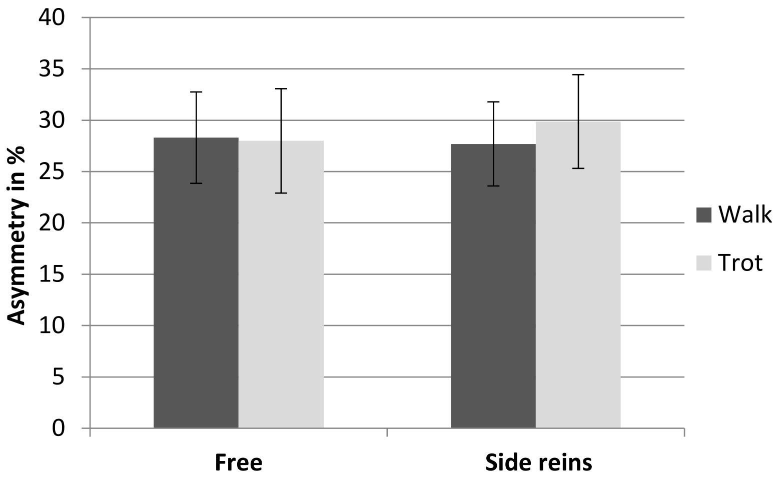

Fig. 21: Mean vertical movement asymmetry of the pelvis marker in free moving horses and horses equipped with side reins.

4.5 Hypothesis 5: The vertical movement asymmetry of head, trunk and croup differs, if the supporting limb lame horse is bended to the left or the right through asymmetric long side reins in trot.

Neither in the forehead nor in the TH12 marker there is a significant difference in the vertical movement asymmetry, if the horse is bended to one side through side reins in comparison to free horses, horses with side reins and horses bended to the other side (p between 0.71 and 1.00) (Fig. 22). In this series of measurements, it is repeatable that the head has a greater vertical motion asymmetry than the trunk (p = 0.039).

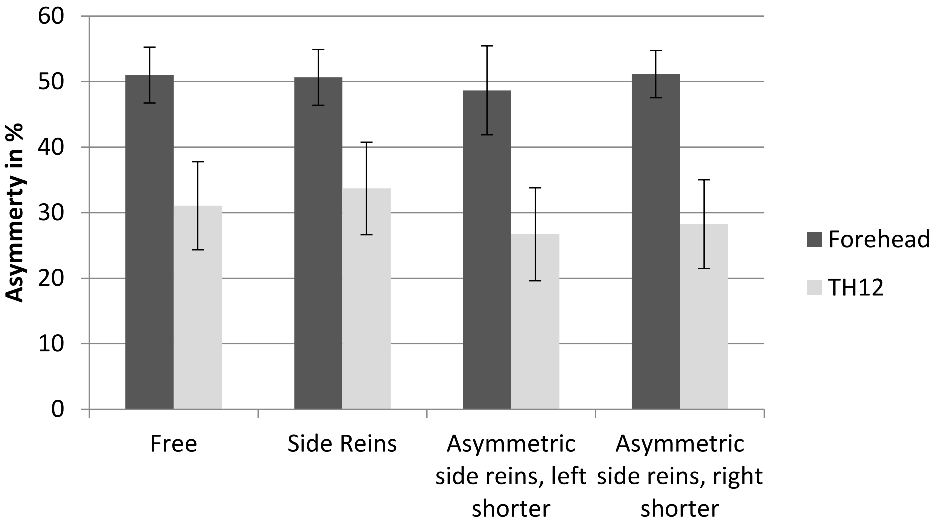

Fig. 22: Mean vertical movement asymmetry of the head and trunk marker in trot in horses moving free, equipped with side reins of equal and asymmetric length.

The mean vertical movement asymmetry of the pelvis (Fig. 23) is a bit lower for bending the horse to the left (22.28 %) than to the right (26.83 %), with side reins of equal length (27.74 %) or the free moving horses (27.44 %). However, there is no significant difference in any comparison (p between 0.28 and 1.00).

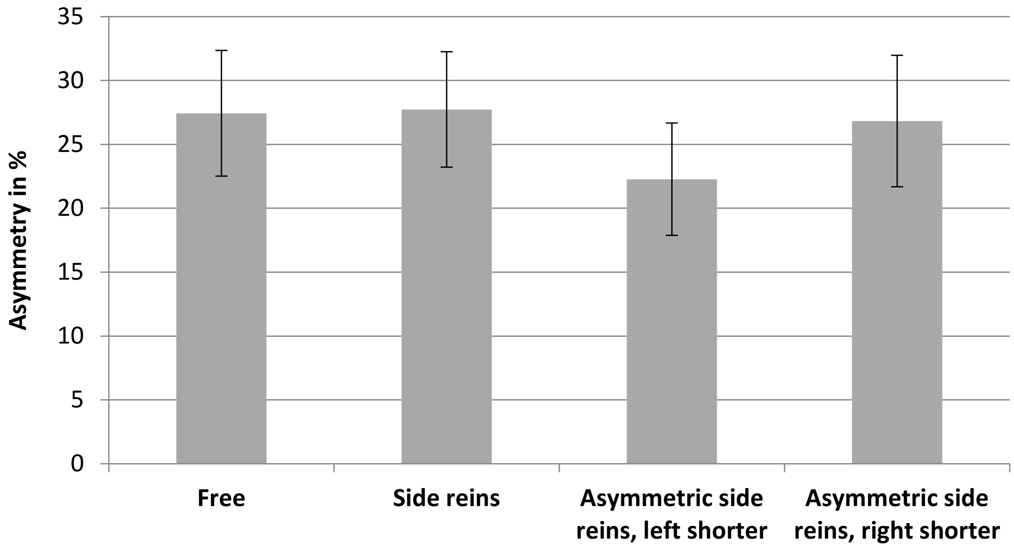

Fig. 23: Mean vertical movement asymmetry of the pelvis marker in trot in horses moving free, equipped with side reins of equal and asymmetric length.

5. Discussion

Comparing vertical head and trunk movement we can conclude, that observing the head is more useful to detect forelimb lameness for the human eye. The results are in line with earlier studies, such as the Buchner 2016 study or the study of Loscher et al. 2016. For the human eye a greater range of vertical movement and higher asymmetry is more easy to observe and can detect lameness hypothetically with a higher sensitivity. Additionally, the trunk shows comparably less asymmetry in trot (hypothesis two), what is also an argument against the observation of the trunk for forelimb lameness. For the interpretation of the vertical trunk movement data, also the rotary movement of the spine needs to be considered. As the rotation leads to a small circular movement of the attached markers in the transverse plane, the cameras capture vertical up- and downwards movement due to this, too (Rhodin et al. 2005). This could influence the measured vertical movement curve artificially, even if it can be assumed as only a small influence and is neglected in this study.

The withers marker was used to differentiate between real or compensatory lameness in this study, but this had no consequence for the analysis of asymmetry of the data. As there are horses with and without compensatory lameness, some horses have more complex dynamics of load redistribution than others do. Therefore, the effect of side reins could also have a more complex effect on the horse’s lameness symptoms in these cases. But as compensatory lameness as symptom follows the same biomechanical principles, no reason was apparent to investigate this separately. The data have been analyzed in the same pool with the data of real lameness.

Concerning the presentation of the horse in walk or trot, the results of hypothesis two show, that for the head and pelvis movement asymmetry there is no significant difference between both gaits. This means that for these two most important observation points in the diagnostic of supporting limb lameness, the results in walk and trot do not need to be interpreted with different weighting. Hypothesis 2 can be partially supported for the movement of the trunk, which is usally not considered for routine lameness diagnostic. A possible explanation for the smaller asymmetry of the trunk movement in trot could be, that due to different gait mechanics the horse stabilizes the trunk in a different way.

Instead of trot, one horse was pacing. Only few data (Seeherman 1991) are available about the differences between trot and the pacing gait in lameness and they have been neglected in this study.

About the use of side reins, in walk there is no restriction of the vertical head movement asymmetry, but even a small significant enhancement. A possible explanation could be a restriction of the amplitude of the head nod in general, which is mathematically represented by the first harmonic sinusoidal wave. When wearing the side reins the horse is still able to lift and lower its head, not in the same pattern of free moving horses, but with the confinement still in a substantial amount. If the horse is still doing the same load redistribution (fundamental wave) to avoid pain in the stance phase, the asymmetric component on the whole sinusoidal curve gets relatively bigger. To confirm this, more investigation about the restriction of the "sound" head nod through side reins in general is needed. In trot the enhancing effect on the asymmetry is not as pronounced as in walk and not significant. Hypothetically this could be explained by a generally smaller head nod in trot than in walk (Buchner, H. H. et al. 1996, Weishaupt 2008). Following the suggestions above, if the amplitude of nodding is smaller itself, the amount of movement restriction through side reins is also smaller. Therefore, it can be assumed that the influence of the asymmetrical component gets relatively less more pronounced on head nodding than in walk.

What does this increase in vertical head movement asymmetry with side reins mean for the horse? Does it mean a more or less efficient load redistribution and lower or higher pain? Or is it only a mathematically and not physically relevant effect? As the vertical movement asymmetry is only one factor in the mechanics of loading and unloading, these questions cannot be answered. An investigation with force plates would be useful to measure if there is an actual difference in load distribution in between the limbs if the horse moves with and without side reins (Weishaupt 2008).

The amount of vertical trunk movement asymmetry has not been influenced significantly by the modification of the head- and neck position through side reins. The effects of this posture confinement does not seem to reach the trunk in a considerably amount. Hypothesis 4, about the influence of side reins on the vertical movement asymmetry of the croup, can also be falsified. It can be suggested, that the tension on the passive locomotion structures like the *ligg. nuchae* and *supraspinale* does not change in a relevant amount. So the mechanics along the spine are not influenced significantly and the effect is not transferred considerably over the back to the trunk and pelvis.

As already mentioned, a hind limb lame horse can redistribute the load from the painful hind limb to the contralateral hind limb, but in cases of compensatory lameness also to the front limbs trough asymmetric head and neck movement. We could expect that restricting the head movement in these horses could increase the vertical pelvis movement asymmetry, because the horse is restricted in using the head to compensate load and therefore has to compensate more load in between its hind limbs. But as already mentioned the data are mixed with horses that do not have compensatory forelimb lameness, and in real forelimb lameness the vertical movement asymmetry of the head is also not restricted. So the horses are still able to use their head movement for compensation and it seems not to be necessary to increase the vertical croup movement asymmetry in a significant amount. For the measuring of the vertical croup movement also the rotation of the pelvis needs to be considered (Buchner et al. 1993). Like in the trunk it could influence the measured vertical movement curve of the marker, though this is neglected in the analysis of the data.

For hypothesis five, unfortunately, not have enough data have been generated to assess the effect of having the shorter side rein ipsi- or contralateral to the lame limb. As the data of bending the neck towards the side of the lame limb and in the opposite direction are summed up, the effects are suspected to neutralize each other. The asymmetric side reins measurement series have only been done in trot and exact information, of how short the shorter rein was, is missing. Hypothetically there could be an effect of asymmetric side reins, as not only a vertical adaption in the head and neck position happens, but also a lateral. So a force to one side occurs and therefore the horse needs to distribute load asymmetrically to maintain balance. In the study of Rhodin et al. 2013 an effect of lunging horses on a circle, also moving with lateral asymmetry, influenced the symptoms of the induced lameness. Due to asymmetry in the spine, an influence over the back to the croup and hind limbs is also imaginable.

As only one symptom of supporting limb lameness, the vertical movement of specific points of interest, is observed in this study, no conclusions about other biomechanical aspects of lameness can be made. Therefore, the results cannot be transferred to suspension phase lameness, for example. The manifold and complex gait adaption mechanisms in lameness, which give an overall impression to the observer, are not represented in this study. Further the causes of lameness in these horses are not known, or if they have a mixed movement pattern with a suspension phase component in their lameness. As this is not expected to affect the results and interpretation of the vertical movement asymmetry, this was neglected.

The system used in this study to classify degrees of lameness does not correspond to the systems normally used by practitioners. These are usually not based solely on vertical asymmetry, but also on other factors such as the constancy of symptoms, the footfall, or the detectability of symptoms in different gaits (American Association of Equine Practitioners, Lischer and Rheinfeld 2018). So the degrees of lameness are not directly transferrable to how clinicians would judge them.

Instead of vertical movement asymmetry in percentages, there also exist more methods with different advantages that are commonly used to calculate movement asymmetry. Examples are using vector sums of absolute differences in ranges of motion (Rhodin et al. 2017) or kinetic methods like measuring differences in ground reaction forces (Weishaupt 2008) .

The central question of the study can be answered by the fact that correctly (according to FN) used side reins only cause a slight increase in the asymmetry of the head nod in supporting limb lame horses during walk. This does not necessarily mean that lameness in walk is easier to detect with the human eye when the horse is equipped with side reins. This could also depend on how much the head nod is restricted in general, and if the human eye is more sensitive to actual changes in the movement range or changes of percentages of asymmetry. The same applies to the falsified hypotheses. In the comparisons with no significant change in asymmetry, the asymmetry can theoretically stay the same if the amplitudes of the fundamental wave and the first harmonic wave get restricted in the same relation. So the meaning of this results for the daily lameness diagnostic routine remains not fully clear. To figure out the actual usefulness or restraint of side reins to practitioners in lameness diagnostic, a study including the judgement of veterinarians would be necessary.

From this study we cannot conclude, if common reins of the rider cause a disguise or enhancement of lameness symptoms. A rider has much more options of influencing head and neck position, as the rider’s hands are in a variable and adjustable position in connection with the horse’s mouth. The lengths of the reins differ during riding and between different disciplines (McLean and McGreevy 2010). Some studies show an influence of the rider to movement asymmetry of horses (Byström et al. 2020, Persson-Sjodin et al. 2018). Different types of auxiliary reins also have different effects on the head and neck position (Miesner 2007), so for each type of them the line of maximal movement of the horse's head has a different shape and could influence the lameness biomechanics in different ways. If the side reins would be adjusted more short, what is also a common practice in horse training (McLean and McGreevy 2010), the radius for vertical head movement gets smaller. An assessment with side reins of different lengths would be further interesting to see if with shorter lengths the head movement starts to become too restricted for sufficient weight redistribution.

6. Summary English

Diagnostics and management of lame horses plays an important role in the everyday routine of veterinarians and is of great economic and animal welfare importance in equestrian sports. The aim of the study was to figure out, if side reins have an influence on the vertical movement asymmetry of head, trunk and croup as major symptoms of supporting limb lameness. Side reins are common auxiliary reins in horse training to achieve a desired, ventroflexed head and neck position.

Fifteen horses of different breeds, ages, and causes of lameness were kinematically examined on a high-speed treadmill. While the horses showed an average vertical movement asymmetry of 51.06 % at the forehead in trot, significantly less asymmetry (34.01 %) was measured at the twelfth thoracic vertebra (trunk). The mean vertical pelvis movement asymmetry was 27.89 % in trot. A significant difference in asymmetry between walk and trot is only apparent at the trunk (walk: 41.07 %, trot: 26.96 %). In the comparison with or without side reins only in walk a significant enhancement of vertical head movement asymmetry was apparent (free: 45.62 %, side reins: 54.87 %). In trot this difference is not significant, like for the trunk and the pelvis no difference with side reins is apparent in general.

As the influence of side reins on the actual range of motion of these points was not analyzed in this study, it remains unclear if the enhancement of vertical head movement asymmetry in walk with side reins is more a mathematical effect than an actual change in load redistribution.

To assess the influence of side reins on the outcome of visual motion analysis by veterinary practitioners, further investigation would be necessary. The same applies to the influence of shorter or other auxiliary reins and the rider's reins.

7. Zusammenfassung

Die Diagnostik und das Management von lahmenden Pferden spielt eine wichtige Rolle im tierärztlichen Alltag und ist im Pferdesport neben dem Tierschutzaspekt von großer wirtschaftlicher Bedeutung. Das Ziel der Studie war es, herauszufinden, ob einfache Ausbindezügel einen Einfluss auf die vertikale Bewegungsasymmetrie von Kopf, Rumpf und Kruppe als Hauptsymptome der Stützbeinlahmheit haben. Einfache Ausbindezügel sind übliche Hilfszügel im Training von Pferden, um eine gewünschte, ventroflexierte Kopf- und Halsposition zu erreichen.

Fünfzehn Pferde verschiedener Rassen, Altersklassen und mit unterschiedlichen Lahmheitsursachen wurden auf einem Hochgeschwindigkeitslaufband kinematisch untersucht. Während die Pferde in Trab eine durchschnittliche vertikale Bewegungsasymmetrie von 51,06 % an der Stirn zeigten, wurde am zwölften Brustwirbel (Rumpf) eine signifikant geringere Asymmetrie (34,01 %) gemessen. Die durchschnittliche vertikale Bewegungsasymmetrie des Beckens betrug 27,89 % im Trab. Ein signifikanter Unterschied in der Asymmetrie zwischen Schritt und Trab zeigt sich nur am Rumpf (Schritt: 41,07 %, Trab: 26,96 %). Im Vergleich mit oder ohne Ausbindezügel zeigte sich nur im Schritt eine signifikante Erhöhung der vertikalen Bewegungsasymmetrie des Kopfes (frei: 45,62 %, Seitenzügel: 54,87 %). Im Trab zeigt sich dieser Unterschied nicht, wie sich auch beim Rumpf oder beim Becken im Allgemeinen kein Unterschied mit Ausbindezügeln zeigte.

Da der Einfluss der Ausbindezügel auf die absolute vertikale Bewegungsspanne dieser Punkte in dieser Studie nicht analysiert wurde, bleibt unklar, ob die Verstärkung der vertikalen Asymmetrie der Kopfbewegung im Schritt mit Seitenzügeln eher ein mathematischer Effekt als eine tatsächliche Veränderung der Lastumverteilung ist.

Um den Einfluss der Ausbindezügel auf das Ergebnis der visuellen Bewegungsanalyse durch tierärztliche Praktiker zu beurteilen, wären weitere Untersuchungen erforderlich. Dasselbe gilt für den Einfluss kürzerer Ausbindezügel, andere Hilfszügel und die Zügel des Reiters.

8. List of abbreviations

AFHW	amplitude of the first harmonic wave
AFW	amplitude of the fundamental wave
AG	Aktiengesellschaft (corporation)
Ao. Univ.-Prof.	Extraordinary Professor of University
art.	articulatio
As. F	vertical movement asymmetry of the head
As. H	vertical movement asymmetry of the croup
c.	compensatory
C2 – C6	cervical vertebre numbers 2 - 6
cm	centimeter
Corp.	corporation
D	degree of lameness
DCM	duration of one movement cycle
Dipl. ACVS	Diplomate of the American College of Veterinary Surgeons
Dipl. ECVS	Diplomate of the European College of Veterinary Surgeons
Dipl.-Ing.	Diplom-Ingenieur
Dr. med.vet.	doctor medicinae veterinariae
Dr. techn.	doctor technicae
et al.	et alii
FEI	Fédération Equestre Internationale
fig.	figure
FN	Fédération Équestre Nationale of Germany
HZ	hertz
Inc.	incorporated
LED	light-emitting diodes
LH	left hind limb
lig.	ligament
ligg.	ligaments
m.	musculus
max	maximum
min	minimum
mm	millimeters
mm.	musculi

p	level of significance
PD	pelvis height difference
RF	right forelimb
RH	right hind limb
s	seconds
s.	sound
TH12	thoracic vertebra number 12
Univ.-Prof.	Professor of university
VUW	University of Veterinary Medicine Vienna

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