Aus der Klinik für Pferde
Chirurgie, Orthopädie, Innere Medizin und Bildgebung
Freie Universität Berlin

Assessment of head and pelvic asymmetry in horses evaluated objectively under different conditions using body-mounted inertial sensors

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For my Family –

Especially for my Mother

Contents

I. Introduction

Lameness in horses remains one of the most common medical problems causing serious consequences for both owners and animals including financial loss and shortened working career of the animal (Keegan et al. 2011, Keegan et al. 2012, Marshall et al. 2012, McCracken et al. 2012, Keegan et al. 2013). The early and correct evaluation of the lameness is essential to provide prompt and effective treatment in order to increase the chances of healing. Evaluating lameness generally consists of seeing the horse move at the walk and trot (Keegan,et al. 2011, Marshall et al. 2012). Vertical head and pelvic movement asymmetry are common and accepted parameters in fore- and hind-limb lameness evaluation for observing and measuring lameness in horses (Wyn-Jones 1988, Barr 1997, Stashak 2002, Bassage 2011, Dyson 2011, Lopez-Sanroman et al. 2012). Visual lameness evaluation in horses is considered to be a subjective assessment method. It is well recognized that the inter – observer agreement during subjective lameness evaluation performed by equine clinicians are not always reliable especially in low grade lame horses (Keegan et al. 1998, Arkell et al. 2006, Fuller et al. 2006, Keegan et al. 2010) and bias can adversely affect the correct evaluation of lameness (Arkell et al. 2006, McCracken et al. 2012). Furthermore the agreement is significantly lower in unexperienced equine practitioners compared to experienced veterinarians (Keegan et al. 2010, Hammarberg et al. 2014). Objective methods of lameness evaluation have the potential for increased sensitivity of measurement, with more precise differentiation of low grade lameness and without potential bias of the observer. Therefore objective measurement systems are warranted and various systems have been introduced in the past 20 years. Kinematic gait analysis is one of the oldest methods of evaluating movement, dating back to the late 19th century. This aspect of gait analysis describes the motion of objects, quantifies the positions, velocities, accelerations and angles of anatomical points, segments and joints in space. It is performed using a series of cameras and non-reflective or reflective markers placed on the subject's skin over specific anatomic landmarks used for reference points, approximating centers of joint motion, indicating bony prominences or points measured a specified distance from a specified landmark. Stationary force plates are the most commonly reported method of objective lameness evaluation. These force plates are highly sensitive and reliable (Marshall et al. 2012), but mobile and easy to use, body mounted inertial sensor systems have been used more often in recent years (Keegan et al. 2012). Inertial sensors that are mainly used in aerospace and the automotive industry for stabilization and navigation are small devices, which measure acceleration (accelerometers) or angular velocity (gyroscopes) (Keegan et al. 2013).

The body-mounted inertial sensor system used in this study provides an objective evaluation of fore- and hind-limb lameness by measuring head and pelvic vertical movement asymmetry (Keegan et al. 1998, Kelmer et al. 2005, Keegan 2007, Keegan 2010, Keegan et al. 2010, Keegan et al. 2011, Keegan et al. 2012, Marshall et al. 2012, McCracken et al. 2012, Keegan et al. 2013).

Vertical head movement asymmetry has been reported as the vector sum (VS) of maximum (Hmax) and minimum (Hmin) head height difference in millimeters (mm) between left and right halves of each forelimb stride, which represents an overall measurement of head movement asymmetry in both the downward and upward directions:

$$(\mathrm{VS} = \sqrt{(\mathrm{H_{max}})^2 + (\mathrm{H_{min}})^2})$$

Side of lameness is determined by sign of Hmin, or minimum head height during right forelimb stance minus minimum head height during left forelimb stance, with positive values indicating right forelimb, and negative values indicating left forelimb lameness. In this 2-component model of head movement evaluation Hmax and Hmin are conceptually related and not separately evaluated. Thus for forelimb lameness, VS is a single dependent variable for forelimb lameness.

Vertical pelvic movement asymmetry is reported as the maximum (Pmax) and minimum (Pmin) pelvis height difference in millimeters (mm) between left and right halves of each stride, with Pmin associated with decreased downward movement in the first half of stance of the hind limbs and Pmax associated with decreased upward movement during the second half of stance of the hind limbs. Positive values of Pmax and Pmin indicate asymmetric pelvic movement due to right hind limb lameness and negative values indicate asymmetric pelvic movement due to left hind limb lameness. In this 1-component model of pelvic movement evaluation Pmax and Pmin are conceptually unrelated and therefore separately evaluated as dependent variables for hind limb lameness.

The Lameness Locator™ includes a tablet computer for data analysis and 3 inertial sensors, attached to the head, right forelimb pastern and pelvis (Keegan 2010). Using this tool provides an easy to use technology to objectively evaluate the gait pattern of horses under different conditions. For this thesis the Lameness Locator was used to examine the feasibility of a body mounted inertial sensor system in two different clinically relevant settings using a group of horses and comparing the data under different conditions.

Evaluation of the inertial sensor system used in these studies was evaluated previously and it was found that reliability and detection rate of lameness in horses trotting in a straight line was acceptable for clinical use and for research purposes (Keegan et al. 2011). Furthermore the Lameness Locator has been validated in previous studies, to be more sensitive in the detection of induced lameness when compared to experienced equine clinicians (McCracken et al. 2012). Using precise measurements for detection of head and pelvic asymmetry, the lameness locator has become a useful tool over the past year for detecting low grade lameness in horses as well as to objectively validate statements in equine lameness examination.

Sedative agents administered to horses can be necessary during a lameness examination to facilitate the diagnostic analgesia in certain patients (Buchner et al. 1999, Stashak 2002, Bassage 2011, Wyn-Jones 1988, Barr 1997). However, these drugs may provide analgesia, induce ataxia (Bassage 2011, Alitalo et al, 1986, Garcia-Villar et al. 1981, Daunt et al 2002, Lopez-Sanroman et al. 2012, Seo et al. 2011, Cruz et al. 2011) or other proprioceptive deficits (Buchner et al. 1999, Ricketts 1986), which subsequently may interfere with the observation of lameness amplitude (Wyn-Jones 1988, Barr 1997). This is especially worrisome for horses with mild lameness, where detecting small changes in the locomotion pattern is necessary (Bassage 2011).

The aim of the first study was to evaluate the effect of a low-dose alpha-2 agonist on the measurement of forelimb and hind limb lameness by measuring asymmetry of vertical head and pelvic movement with body mounted inertial sensors.

Extreme forces of impact or loading to the horse’s hoof can be experienced when riding on concrete and asphalt or simply when stepping on a rock while moving at high speed. These conditions may adversely affect the sensitive hoof tissue in domesticated horses and as a result many of these horses are shod (Back et al 2013, Clayton et al. 2011, Curtis 2006, Hertsch et al 1997, Humphrey 1995, Leisering et al 1982, Leslie 1977, Möller 1915, Schwendimann 1937). An alternative approach to a regular hoof shoe would be to protect the hoof when necessary and to expose it when not. Several brands of tie-on hoof shoes have commercially been marketed (Hertsch et al. 1997)

The aim of the second study was to assess the head and pelvic asymmetry in healthy riding horses using such a hoof clog compared to their normal shoeing and barefoot. A particular interest was to evaluate whether the hoof clog could prevent any lameness that might develop in horses being trotted barefoot on a hard surface immediately after trimming.

II. Research publications in peer-reviewed journals

II.I Effect of sedation on fore- and hindlimb lameness evaluation using body-mounted inertial sensors

Publication: Equine Veterinary Journal May 2015

[1]Rettig M. J.*, [1-2]Leelamankong P., [1-2]Rungsri P.,[1]Lischer C.J.

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*see complete publication in appendix 9.1.1

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II.II Immediate effect of Dallmer Hoof Clogs on head and pelvic asymmetry using body mounted inertial sensors

Publication: Pferdeheilkunde May/June 2016

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Please download this part.

http://www.pferdeheilkunde.de/de/fundus/

III. Appendix

III.I Publications

- Effect of sedation on fore- and hindlimb lameness evaluation using body-mounted inertial sensors
    - Supplement I
    - Supplement II
    - Supplement III
- Immediate effect of Dallmer Hoof Clogs on head and pelvic asymmetry using body mounted inertial sensors

IV. Declaration of the work distribution of the authors in the research publications

IV.I Effect of sedation on fore- and hindlimb lameness evaluation using body-mounted inertial sensors

Authors: Rettig M. J., Leelamankong P., Rungsri P., Lischer C.J.

Year: May 2015

Journal: Equine Veterinary Journal

	M.J. Rettig	P. Leelamankong	P. Rungsri	C.J. Lischer
Study Design	60%	-	-	40%
Study Execution	50%	15%	15%	20%
Data Collection	50%	25%	25%	-
Data Analysis and Interpretation	60%	-	-	40%
Preparation of the Manuscript	70%	-	-	30%

IV.II Immediate effect of Dallmer Hoof Clogs on head and pelvic asymmetry using body mounted inertial sensors

Publication: Pferdeheilkunde, May/June 2016

Rettig M. J., Lischer C.J.

	M.J. Rettig	C.J. Lischer
Study Design	50%	50%
Study Execution	70%	30%
Data Collection	100%	-
Data Analysis and Interpretation	60%	40%
Preparation of the Manuscript	70%	30%

V. Discussion

The lameness locator, a body-mounted-inertial sensor system was designed for equine practitioners as a tool for the detection and evaluation of low grade lameness in the horse (Keegan 2010). The horses are instrumented with three inertial sensors: one uni-axial accelerometer is attached to the head collar between the ears of the horse. A second accelerometer is placed on the midline between the tuber sacrale of the most dorsal aspect of the pelvic region. These measure the vertical accelerations of the pelvis and head during motion. A uni-axial gyroscopic sensor is attached to the dorsal aspect of the pastern on the right forelimb to measure angular velocity of this specific limb. Data measured is transmitted to a hand-held tablet computer in real time, where a custom-designed algorithm is used for detection and quantification of forelimb and hindlimb lameness (Keegan 2010). Thresholds for head- and pelvic asymmetry have been estimated and validated in multiple studies. This threshold for hind limb lameness between normal and lameness have been estimated to be +/- 3mm and for forelimb lameness +/- 6mm respectively. In the first study (sedation study) a few horses in each group had evidence of both, vertical head and pelvic movement asymmetry. In these cases the determination of the primary lame limb was based on the amplitude of asymmetry (% above the threshold) and if the amplitudes of asymmetry were similar, on the distribution (ipsilateral or contralateral) of the asymmetries. Horses with contralateral distribution of asymmetry (apparent forelimb and hind limb lameness on opposite sides) were assigned as having primary forelimb lameness and horses with ipsilateral distribution of asymmetry (apparent fore- and hindlimb lameness on the same side) were assigned as having primary hind limb lameness. This method of determining the limb with primary lameness is based on known compensatory movements in the opposite half of the body appearing as false 'lameness' and is known as 'The law of Sides' (Keegan 2007, Kelmer et al. 2005, Weishaupt et al. 2004, Weishaupt et al. 2006). By using these values as expected ranges for random change, numbers of horses staying the same, worsening (increased asymmetry) and improving (decreased asymmetry) were computed.

Horses in both studies were selected from a riding school herd and most animals showed a mild asymmetry measureable using the body mounted inertial sensor system. It has to be questioned if a slight asymmetry above threshold detectable with body mounted inertial sensors in horses has to be considered as normal, since it is commonly measured in horses without a subjective detectable lameness and if every asymmetry measured above threshold is equivalent with a lameness of the animal. The high number of horses in this study with asymmetry in one or more limbs above threshold, which were chosen for the study as 'normal' riding school horses without any lameness noticed by the owner is somewhat worrisome.

Following the suggestions of the lameness locator software, the majority of horses working in this riding school every day would be lame. One possible explanation could be the mean age of these horses which was higher than the average population of horses presented for lameness examination during routine veterinary work. It is possible, that lameness due to arthritic changes is more likely to occur in an older population of horses. However, a detailed investigation including local analgesia and imaging would be necessary to investigate the underlying cause of the lameness or the asymmetry above threshold.

Asymmetry in fore- and hind-limbs could also be the result of tension in the horses back and/or neck due as reaction to the unknown environment. This tense musculature might be responsible for a certain degree of asymmetry in the locomotion pattern detectable by the sensors. Further studies could evaluate more 'normal' riding horses during their routine work using body mounted inertial sensors, to get a better understanding on the reliability of the pre-determined asymmetry – threshold as well as what the normal asymmetry in a riding horse population would be.

The threshold of the inertial sensor system was determined before in multiple studies as mentioned previously (Keegan 2007, Keegan 2010), but looking into the results of this study it could be an explanation, that this threshold was set too low for the average horse or the horses used in the study had a lameness. All horses were evaluated subjectively before they were included into the study and only horses with a lameness degree not higher than 2 out of 5 (AAEP-Scale) were included into the study. It was not further investigated, if the subjective assessment was corresponding to the results of the lameness locator in the individual horse. This would be another interesting analysis to perform. Overall the first author, who performed the subjective examination on arrival for including horses into the first study classified 34 out of 44 (77%) horses as lame in at least one limb.

Another possible explanation of the high number of horses above asymmetry – threshold in this study could be the untrained eye of most horse owners in the detection of lameness. Many horse owners and riders, if not experienced struggle to recognize a lameness in horses, especially in the hind limb and in low grade lame horses. It could be shown, that more horses in the study showed a hind limb asymmetry compared to a front limb asymmetry. It is well recognized, that hind limb lameness in horses is far more difficult to recognize even for experienced veterinarians (Keegan 2007, Keegan 2010) why it could be an explanation, that it is even more difficult for owners and riders. Evaluating these horses subjectively by an experienced veterinarian could provide further understanding of the detection rate of lameness by an unexperienced owner or rider.

Sedating difficult horses during a lameness evaluation to facilitate diagnostic analgesia is sometimes necessary, when horses do not respond to physical restrain (Bassage 2011). The purpose of the first study was to objectively measure the effect of low-dose (0,3mg/kg) sedation on the gait of horses in trot using common indicators of forelimb and hind-limb lameness as measurement, such as vertical movement of the head and pelvis (Wyn-Jones 1988, Barr 1997, Stashak 2002, Bassage 2011). The absence of significant change in amplitude of forelimb and hind limb lameness in the xylazine treatment group at both 20 and 60 minutes post treatment for either all horses or for horses with pre-existing lameness is supportive evidence that this amount of sedation does not interfere or mask the exhibition lameness, and thus can be effectively used if needed in the clinical situation.

It is interesting to note that in this study some of the horses in the saline group had a greater vertical head movement asymmetry at times 20 and 60 than at time 0. This could be interpreted as an increase in forelimb lameness. When horses in the saline group were interpreted individually most stayed the same but 4 horses (between time 0 and time 20) and 5 horses (between time 0 and 60) had greater vertical head movement asymmetry that could be interpreted as either becoming lame (when previously not) or worsening in forelimb lameness. However, in the xylazine group, fewer (1 between time 0 and time 20 and 2 between time 0 and time 60) had increased asymmetric head movement. This increase in lameness in some horses in the saline group is concerning since the horses had head movement asymmetry consistent with developing or increased forelimb lameness without apparent provocation. This could have interfered with the correct evaluation of lameness should a block indeed have been performed. This apparent increase in forelimb lameness after time 0 could have been caused by masking of lameness at time 0, perhaps by initial excitement of the horse at the initial examination, or the act of lameness evaluation itself (trotting the horse up and down on an asphalt surface) generated or increased forelimb lameness. Results of this study support a contention that it is important to first determine that the lameness being evaluated is not changing, perhaps by performing repeated examinations a few minutes apart or, if appropriate in the particular case, by exercising the horse for a few minutes before evaluation. Certainly, some attempt to create “stable” forelimb lameness should be made before launching into local anesthesia procedures.

In the first study there were fewer horses with pre-existing forelimb than hind limb lameness, which may have affected our ability to detect small differences in forelimb lameness between groups and times. No difference in head movement asymmetry associated with lameness could be detected in the xylazine group. However, 4 out of 9 horses with existing forelimb lameness in the xylazine group had decreased head movement asymmetry (less forelimb lameness) at 60 minutes post treatment. The mean decrease in VS in these 4 horses was 14.1 mm, well above the 95% confidence interval for repeatability and what would be considered random change. By contrast, in the saline group, only 2 horses out of 7 with existing forelimb lameness were improved 60 minutes post treatment. Although the numbers of horses improving in forelimb lameness were not statistically significant different between saline and xylazine treatment groups, the fact that almost 50% of horses treated with low dose xylazine would have been considered improved at 60 minutes without blocking is troublesome. The decreased head movement asymmetry in these 4 horses after xylazine treatment is likely not only due to sedation, but also caused by these horses being more relaxed and used to the study protocol. Signs of sedation were strongest 20 minutes after treatment, when the decrease in head height asymmetry in the xylazine treatment group was less than at 60 minutes after treatment. It is possible that residual analgesic effects of xylazine may be present at 60 minutes in these 4 horses, after clinical signs of sedation have disappeared. The systemic half-life of xylazine after intravenous administration is approximately 50 minutes with peak effect, as measured by response to nociceptive stimuli, of 5 to 20 minutes after administration (Garcia-Villar et al. 1981, Ringer et al. 2013). Duration of sedation and analgesia generally coincide and last for around 50 minutes, however, assessment of true analgesic effects in animals (compared to humans) is difficult, approximate and analgesia sufficient to ameliorate lameness may persist longer.

Head and pelvic movement asymmetry has been shown to be influenced by speed of movement, which was estimated in this study by measuring stride rate. Stride rate, along with stride length, is a component and estimate of speed. Stride rate increases non-linearly over a wide range of speed, but at the low stride rates of this study, the relationship is nearly linear (Leach et al. 1986). In another study in which stride rate and speed of movement were simultaneously measured, 15 minutes after a higher dose of xylazine, a decrease in stride rate by 22% occurred with a simultaneous decrease in speed of movement of 24% (Lopez-Sanroman et al. 2012). In this study mean stride rate decreased in the xylazine group 20 minutes after treatment by 3%, which was significantly more than the saline group. However, this small decrease in stride rate (3%), though statistically significant, and likely equivalent to a decrease in speed of movement of < 5%, was probably not clinically significant. Our finding that all horses with forelimb lameness in the xylazine group at 20 minutes were unchanged in forelimb lameness, when stride rate was significantly different, but 5 out 9 at 60 minutes had change in amplitude of forelimb lameness, when stride rate was not significantly different, supports this contention.

In conclusion, the results of this first study generally support the use of low-dose xylazine sedation without reversal in recalcitrant horses to facilitate blocking without masking of lameness 20 and 60 minutes post sedation, especially for evaluation of hind limb lameness. However, low-dose sedation may strongly affect the evaluation of vertical head movement asymmetry in individual horses up to 60 minutes post sedation and care should be taken especially when evaluating mild forelimb lameness. Further investigations with other sedative agents, dosages, and regimens, should be performed before extrapolating the results of this study too broadly.

The purpose of the second study was to objectively evaluate whether applying hoof clogs to horses freshly trimmed feet would prevent (or even cause) forelimb or hind limb lameness. Although the mean level of lameness as measured by head and pelvic movement asymmetry was not significantly different between any of the treatments (with shoes, barefoot after trimming, and with clogs) in any group, we did find some interesting trends when clogs were applied to the freshly trimmed foot and evaluated before allowing the horse to trot on a hard surface. More horses were either unchanged in lameness or improved when evaluated wearing the clogs. More horses either developed lameness or had worsening in existing lameness if they were allowed to trot barefoot after trimming.

The hoof clogs were easy to fit and apply for an experienced farrier, and once fitted they were easy to apply and remove. After some brief training, students without any experience in hoof shoe application, could quickly and correctly apply the clogs. All horses fitted with the clogs were trotted for 50 meters before they were re-evaluated objectively. Subjectively, a few horses seemed to have mild increased movement of the limbs for about 5-10 strides, but then all seemed to tolerate the clogs and trot normally within a few meters.

Although not statistically significant there was a trend for Pmin to be higher in group 2 horses (first re-evaluated after trimming and on the third trial evaluated with hoof clogs applied) when evaluated barefoot after trimming, and more horses either developed lameness or had a worsening in lameness when evaluated barefoot after trimming. Pmin is a measure of the impact component of hind limb lameness (Keegan et al. 2011) and pain or sensitivity on impact of the hind limbs may be caused or exacerbated by allowing exercise on hard ground while barefoot immediately after trimming. The application of the hoof clogs may ameliorate this by protecting the bottom of the foot.

Though not statistically significant there was also a small trend for higher Pmax in the horses before removing the shoes. Pmax is a measure of asymmetry hind limb pushoff. Hind limb pushoff effectiveness likely is improved with good hind limb traction and the steel shoes on the asphalt surface may cause slight slippage during pushoff of the hind limbs.

In this study only 10 horses per group were evaluated and no statistically significant effects of the hoof clogs were found.

Results of this study support the contention that applications of these hoof clogs do not cause forelimb or hind limb lameness, are well tolerated, and may decrease concussion when trotting on hard ground. Additional studies with larger numbers of horses, particularly with groups of either completely sound horses or horses with consistent lameness in either the forelimb or hind limb, especially if the lameness focus is within the foot or distal limb joints. Also, other studies in which the horses are fitted and wearing the clogs, and are subjected to exercise and ridden on different surfaces, while traveling in a circle should be conducted.

For both studies the Lameness Locator, a body-mounted-inertial-sensor system was used to objectively evaluate the head and pelvis asymmetry in horses under different conditions. The Lameness Locator, mostly used by equine practitioners around the world for the detection and evaluation of difficult lameness in horses was found to be an easy tool for the purpose of these studies. It was tolerated well by all horses and the data collected between the different trials during the study were easy to analyze and to compare. The Lameness Locator can be used during routine lameness examination where the opportunity to save the data and compare it to previously measured trials is a well-established method of objectively assessing the success of a recommended treatment plan. It is furthermore a great tool for educational purposes and in the future more objectively performed studies will surely be performed. Overall, the Lameness Locator was found to be very useful for an objective comparison of horses examined under different conditions focusing on lameness.

VI. Summary

Lameness remains one of the most common medical problems in working horses. Vertical movement asymmetry of head and pelvis are common and accepted parameters in fore- and hind limb lameness evaluation, but it has been shown before that the subjective evaluation of lameness performed by equine practitioners are not reliable especially in low grade lame horses and that bias can adversely affect the correct evaluation of lameness. The body-mounted inertial sensor system used in this study provides objective measures of forelimb and hind limb lameness by measuring the head and pelvic vertical movement asymmetry. It has been evaluated before for reliability and detection rate of lameness and was found to be sufficiently repeatable to investigate for clinical use.

Diagnostic analgesia is an integral part during an equine lameness examination, but it can be challenging to perform in uncooperative horses. Using sedation in these horses might, because of analgesic and ataxia-inducing effects, interfere with lameness evaluation. Therefore the objective of the first study was to evaluate whether sedation with low-dose xylazine would alter lameness amplitude as measured by body mounted inertial sensors. Therefore 44 horses were randomly split into 2 groups and lameness was measured before and after injection of either xylazine (0,3mg/kg) or saline. Numbers of horses staying the same, improving or worsening were compared between groups at each time interval.

There was no significant difference in head or pelvic movement asymmetry between the xylazine and saline treatment group. However, a few horses with forelimb lameness in the xylazine treatment group showed a large decrease in head movement asymmetry which is equivalent to a decrease in forelimb lameness at 60min post sedation, concluding that a low-dose sedation with xylazine may be used without any concern of potential lameness-masking effects for hind limb lameness evaluation, but caution should be used in horses with forelimb lameness, especially in those of mild severity.

Extreme forces of impact or loading to the horse's foot on completely inelastic surfaces may adversely affect sensitive hoof tissue, resulting in most domesticated horses being shod. The aim of the second study was to assess one method of temporary hoof covering, a hoof clog, to determine objectively if application of a Dallmer Hoof Clog in horses trotting over hard ground would affect the vertical head and pelvic movement asymmetry compared to the normal shod and unshod condition. The particular interest was to determine whether the hoof clog would prevent any lameness that might develop in horses trotting barefoot on a hard surface immediately after trimming. Twenty horses were randomly obtained from a riding school herd

and evaluated objectively using body mounted inertial sensors first with their regular shoeing, barefoot and with a hoof clog applied. Overall there were no significant differences in either group between treatments (regular shoeing, trimmed and unshod, clogs). Even though not statistically significant, there was a trend that horses trotted barefoot developed a slight lameness, which could be ameliorated when applying hoof clogs. Results of this study support the contention that applications of these hoof clogs do not cause forelimb or hind limb lameness, are well tolerated, and may decrease concussion when trotting on hard ground.

The body mounted inertial sensor system 'Lameness Locator' was found to be a very useful tool for an objective comparison of horses examined under different conditions focusing on lameness.

VII. Zusammenfassung

Objektive Untersuchung der Kopf- und Becken-Asymmetrie bei Pferden unter verschiedenen Bedingungen mit Hilfe eines Sensorsystems (Lameness Locator)

Lahmheit ist eines der am häufigsten, medizinischen Probleme bei Pferden. Bei der Beurteilung von Lahmheiten ist die vertikale Bewegung von Kopf und Kruppe ein sehr häufig genutzter und akzeptierter Anhaltspunkt. Studien haben gezeigt, dass die subjektive Evaluierung von lahmen Pferden durch Tierärzte, insbesondere bei leichtgradigen Lahmheiten häufig nicht zuverlässig ist und sich eine vorgefertigte Meinung negativ auf eine korrekte Beurteilung auswirken kann. Das Sensor System, welches in dieser Studie genutzt wurde erkennt Vorderhand- und Hinterhand-Lahmheiten, indem es objektiv die Asymmetrie der vertikalen Kopf- und Kruppen-Bewegung misst. Es konnte gezeigt werden, dass diese Art der Messung verlässlich im Erkennen von Lahmheiten ist.

Leitungsanästhesien sind ein entscheidender Teil innerhalb der Lahmheitsuntersuchung von Pferden, können jedoch bei schwierigen Patienten oft problematisch in der Durchführung sein. Das Sedieren solcher Pferde könnte allerdings, aufgrund der analgetischen sowie ataxie-auslösenden Wirkung den weiteren Verlauf der Lahmheitsuntersuchung beeinflussen. Daher war das Ziel der ersten Studie, zu untersuchen, ob eine Sedierung mit einer geringen Menge Xylazin die Lahmheit, welche mit einem Sensor System gemessen wurde beeinflusst. Hierzu wurden 44 Pferde zufällig in zwei Gruppen eingeteilt und die vertikale Bewegung von Kopf und Kruppe gemessen, nachdem der Hälfte der Pferde Xylazin (0,3mg/kg) und der anderen Hälfte physiologische Kochsalzlösung injiziert wurde. Die Anzahl der Pferde, welche unverändert, verschlechtert oder verbessert waren wurde analysiert und zwischen den beiden Gruppen zu den unterschiedlichen Zeitpunkten verglichen.

Es bestand kein signifikanter Unterschied innerhalb der Kopf- und Kruppen-Asymmetrie zwischen der Xylazin- und der Kontrollgruppe, jedoch zeigten einige Pferde mit einer Vorderhand-Lahmheit in der Xylazin-Gruppe eine deutliche Verringerung der vertikalen Kopf-Bewegung 60min nach Sedation, was mit einer Verringerung der Lahmheit gleichzusetzen ist. Dies lässt die Schlussfolgerung zu, dass eine geringe Menge Xylazin problemlos in der Lahmheitsuntersuchung von Pferden mit einer Hinterhand-Lahmheit genutzt werden kann. Bei Pferden, insbesondere solchen mit einer leichtgradigen Vorderhand-Lahmheit muss die Sedierung mittels einer geringen Dosis Xylazin jedoch kritisch abgewogen werden.

Extreme Kräfte wirken auf die Hufe von Pferden beim Landen und Belasten, insbesondere auf festen, unelastischen Böden, was sich negativ auf das sensible Gewebe im Bereich des Hufes auswirken kann. Aus diesem Grund sind die meisten domestizierten Pferde heutzutage beschlagen. Ziel der zweiten Studie war es eine Alternative zum klassischen Beschlag zu untersuchen. Hierbei wurde untersucht wie ein ‚Dallmer Hufschuh' als ein temporärer Hufschutz die vertikale Bewegung von Kopf und Kruppe im Vergleich zu normalem Beschlag und barfuß beeinflussen würde. Das besondere Interesse lag darauf zu erkennen, ob ein Hufschuh eine Lahmheit verhindern könnte, welche möglicherweise bei Pferden auftritt, die unmittelbar nach dem Abnehmen der Eisen barfuß vorgetrabt wurden. Zwanzig Pferde wurden zufällig aus einer Herde an Reitpferden ausgewählt und objektiv mittels Sensoren System evaluiert. Alle Pferde wurden mit ihrem gewöhnlichen Beschlag, sowie barfuß und mittels aufgeschnalltem Hufschuh untersucht.

Es konnte kein signifikanter Unterschied in der Bewegungs-Asymmetrie zwischen den verschiedenen Huf-Beschaffenheiten nachgewiesen werden (gewöhnlicher Beschlag, barfuß, Hufschuh). Wenngleich nicht signifikant, so konnte jedoch ein leichter Trend erkannt werden, dass Pferde, welche barfuß getrabt wurden eine leichte Lahmheit entwickelten, was sich durch das Aufbringen von Hufschuhen wieder verbesserte. Die Ergebnisse dieser Studie unterstützen die Vermutung, dass diese Art von Hufschuhen keinen Einfluss auf Vorderhand- und Hinterhand-Lahmheit bei Pferden haben, sie gut toleriert werden und in einem gewissen Maß die Erschütterung beim Traben auf hartem Boden verringern können.

Das in diesen Studien genutzte Sensor – System ‚Lameness Locator' wurde als ein sehr nützliches Hilfsmittel angesehen um objektiv einen Vergleich herstellen zu können zwischen Pferden, die unter unterschiedlichen Bedingungen im Hinblick auf Lahmheit vorgetrabt wurden.

VIII. References

Arkell, M., R. M. Archer, F. J. Guitian and S. A. May (2006). "Evidence of bias affecting the interpretation of the results of local anaesthetic nerve blocks when assessing lameness in horses." Vet Rec **159**(11): 346-349.

Back W.; Clayton H. (2013). The role of the hoof and shoeing, Equine Locomotion, 2nd Edition, Saunders, Elsevier

Barr, A. R. S. (1997). Musculoskeletal diseases. Diagnostic techniques in Equine Medicine 2nd Edition. F. G. R. Taylor, Brazil, T.J., Hillyer M.H., Sauter**:** 250-288.

Bassage II, L. H. (2011). Diagnostic Analgesia. Lameness in the Horse 2nd Edition. M. W. Ross, Dyson S.J., Sauter**:** 100-135.

Clayton, H.; Gray S.; Kaiser L.; Bowker R. (2011). Effects of barefoot trimming on hoof morphology, Australian Veterinary Journal **89**:305-311

Curtis, S. (2006). Corrective Farriery – A Textbook of Remedial Horseshoing. Newmarket, R & W Publications

Dyhre-Poulsen P.; Smedegaard H.; Roed J.; Korsgaard E. (1994) Equine hoof function investigated by pressure transducers inside the hoof and accelerometers mounted on the first phalanx. Equine Vet J.**26** (5): 362-366

Friedrich, H. (1931). Über das Wachstum und die Abreibung der Hornwand des Pferdehufes. Berliner Tierärztliche Wochenschrift **47**: 20-21

Fuller, C. J., B. M. Bladon, A. J. Driver and A. R. Barr (2006). "The intra- and inter-assessor reliability of measurement of functional outcome by lameness scoring in horses." Vet J **171**(2): 281-286.

Garcia-Villar, R., P. L. Toutain, M. Alvinerie and Y. Ruckebusch (1981). "The pharmacokinetics of xylazine hydrochloride: an interspecific study." J Vet Pharmacol Ther **4**(2): 87-92.

Hampson B.; Ramsey G.; Macintosh A.; Mills P.; De Laat M.; Pollitt C. (2010). Morphometry and abnormalities of the feet of Kaimanawa feral horses in New Zealand. Australian Veterinary Journal **88** (4): 124-131

Hammarberg, M., A. Egenvall, T. Pfau and M. Rhodin (2016). "Rater agreement of visual lameness assessment in horses during lungeing." Equine Vet J. **48** (1): 78-82

Hertsch, B.; Höppner, S.; Dallmer, H. (1997). Der Huf und sein nageloser Hufschutz. Warendorf, Fn-Verlag

Humphrey, M. (1995). The Horse Shoeing Book. London, Allen J.A.

Jackson J. (1997). Natural Horse: Foundations for Natural Horsemanship, 2nd Edition, Star Ridge Publications

Keegan, K. G. (2007) “Evidence-Based Lameness Detection and Quantification” Vet Clin Equine 23: 403-423

Keegan, K. G., D. A. Wilson, D. J. Wilson, B. Smith, E. M. Gaughan, R. S. Pleasant, J. D. Lillich, J. Kramer, R. D. Howard, C. Bacon-Miller, E. G. Davis, K. A. May, H. S. Cheramie, W. L. Valentino and P. D. van Harreveld (1998). "Evaluation of mild lameness in horses trotting on a treadmill by clinicians and interns or residents and correlation of their assessments with kinematic gait analysis." Am J Vet Res **59**(11): 1370-1377.

Keegan, K. (2010). The Lameness Locator (wireless inertial sensors for detection of lameness in horses). WVOC 2010, Bologna (Italy)

Keegan, K. G., E. V. Dent, D. A. Wilson, J. Janicek, J. Kramer, A. Lacarrubba, D. M. Walsh, M. W. Cassells, T. M. Esther, P. Schiltz, K. E. Frees, C. L. Wilhite, J. M. Clark, C. C. Pollitt, R. Shaw and T. Norris (2010). "Repeatability of subjective evaluation of lameness in horses." Equine Vet J **42**(2): 92-97.

Keegan, K. G., J. Kramer, Y. Yonezawa, H. Maki, P. F. Pai, E. V. Dent, T. E. Kellerman, D. A. Wilson and S. K. Reed (2011). "Assessment of repeatability of a wireless, inertial sensor-based lameness evaluation system for horses." Am J Vet Res **72**(9): 1156-1163.

Keegan, K.; MacAllister C.; Wilson, D.; Gedon, C.; Kramer, J.; Yonezawa, Y.; Maki, H.; Pai, P. (2012). Comparison of an inertial sensor system with a stationary force plate for evaluation of horses with bilateral forelimb lameness. Am J Vet Res **73** (3): 368-374.

Keegan, K.; Wilson, D.; Kramer, J.; Reed, S.; Yonezawa, Y.; Maki, H.; Pai, P.; Lopez, M. (2013) Comparison of a body-mounted inertial sensor system-based method with subjective evaluation for detection of lameness in horses. Am J Vet Res **74**(1): 17-24.

Leach, D. and N. F. Cymbaluk (1986). "Relationships between stride length, stride frequency, velocity, and morphometrics of foals." Am J Vet Res **47**(9): 2090-2097.

Leisering, A.; Hartmann H. (1982). Der Fuß des Pferdes in Rücksicht auf Bau, Verrichtungen und Hufbeschlag. Dresden, Schoenfeld's Verlagsbuchhandlung

Leslie, E. (1977). Horseshoeing Theory and Hoof Care. Philadelphia, Lea and Febiger

Lopez-Sanroman, F. J., R. Holmbak-Petersen, I. Santiago, I. A. Gomez de Segura and E. Barrey (2012). "Gait analysis using 3D accelerometry in horses sedated with xylazine." Vet J **193**(1): 212-216.

Marshall, J.; Lund D.; Voute L. (2012). Use of a wireless, inertial sensor-based system to objectively evaluate flexion tests in the horse. Equine VetJ Suppl **43**: 8-11.

McCracken, M.; Kramer J.; Keegan K.; Lopes M.; Wilson D.; Reed, S.; LaCarrubba, A.; Rasch, M. (2012). Comparison of an inertial sensor system of lameness quantification with subjective lameness evaluation. Equine Vet J **44**(6): 652-656

Möller, H. (1915). Hufpflege, Hufschutz und –beschlag. Berlin, Parey Verlag.

Ringer, S. K., K. Portier, P. R. Torgerson, R. Castagno and R. Bettschart-Wolfensberger (2013). "The effects of a loading dose followed by constant rate infusion of xylazine compared with romifidine on sedation, ataxia and response to stimuli in horses." Vet Anaesth Analg **40**(2): 157-165.

Ruthe, H. (1988). Der Huf. Stuttgart, Fischer Verlag

Stashak, T. S. (2002). Examination for Lameness 5th Edition. Adams' Lameness in Horses. T. S. Stashak. Philadelphia, Lippincott Williams & Wilkins: 113-183.

Strasser H.; (2000). Shoeing: A Necessary Evil?, Sabine Kells Publisher

Schwendimann, F. (1937). Leitfaden des Hufbeschlages. Bern, Zimmermann Verlag

Wyn-Jones, G. (1988). Equine Lameness. Oxford, Blackwell Scientific Publications.

IX. List of Abbreviations

α	Alpha
AAEP	American Association of Equine Practitioners
bwt	Body Weight
CI	Confidence Interval
HHAG	Head Height above Ground
Hmax	Maximum Head Height Difference
Hmin	Minimum Head Height Difference
kg	Kilogram
LF	Left Front
LH	Left Hind
m	Meter
mg	Milligram
min	Minute(s)
ml	Milliliter
mm	Millimeter
Pmax	Maximum Pelvis Height Difference
Pmin	Minimum Pelvis Height Difference
RF	Right Front
RH	Right Hind
VS	Vector Sum
v.s.	versus

X. Oral Presentation

Rettig M. J., Leelamankong P., Rungsri P.,Lischer C.J.
‚The effect of sedation on evaluation of subtle lameness in horses using body-mounted inertial sensors‘
23rd Annual Scientific Meeting, July 3-5, 2014
European College of Veterinary Surgeons
Copenhagen, Denmark

XI. List of publications

XI.I M.J. Rettig, P. Leelamankong, P. Rungsri, C.J. Lischer. Effect of sedation on fore- and hindlimb lameness evaluation using body-mounted inertial sensors. Equine Veterinary Journal, May 2015

XI.II M.J. Rettig, C.J. Lischer. Immediate effect of Dallmer Hoof Clogs on head and pelvic asymmetry using body mounted inertial sensors. Pferdeheilkunde, Mai/Juni 2016

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XIII. Author's declaration of originality

Hiermit bestätige ich, dass ich die vorliegende Arbeit selbständig angefertigt habe. Ich versichere, dass ich ausschließlich die angegebenen Quellen und Hilfen in Anspruch genommen habe.

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