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Foreword

After 32 years, ICEL is back in Utrecht, where it all started under the name 'International Workshop on Animal Locomotion' (IWAL). After a somewhat irregular start, IWAL (from 2004 called ICEL for 'International Conference on Equine Locomotion', later changed to 'International Conference on Equine and Canine Locomotion') took a 4-yearly rhythm in 1996, alternating in the even years with the International Conference on Equine Exercise Physiology (ICEEP) that also featured a section on equine locomotion and biomechanics. The last meeting in this series was in 2016 in London. ICEEP was lucky to have their last pre-COVID meeting in 2018 before the pandemic. Unfortunately, ICEL was severely affected by the COVID pandemic in 2020 and still in 2021. This meant that ICEL could not resume until this year. However, at last, ICEL is back and how! About 90 abstracts can be found in these proceedings only a year after there were 74 biomechanical abstracts at the ICEEP 2022 congress in Sweden, where biomechanics was the largest of all sections. Our field of research is undoubtedly thriving!

However, perhaps the biggest change in the field is not the numerical growth of researchers in equine biomechanics and gait analysis, which is nicely illustrated by the difference between the number of attendees of the 2023 meeting and the 40-odd pioneers who look so proudly into the lens of the (not yet digital) camera when taking the 1991 photo that is displayed on the current ICEL website. Equine locomotion research has always been driven mainly by the wish to improve and objectify locomotion exams, since all equestrian activities are based on the locomotor performance of the horse and orthopaedic disorders are by far the number one concern in (sports) horse medicine. Since the days of Marey and Muybridge, considerable progress has been made in correctly describing and understanding the essentials of equine gait, largely thanks to the enormous developments in motion capture technology and computational power. However, for many decades those novel techniques remained confined to lab environments as they were either too expensive, too cumbersome or too time-consuming for application in daily equine orthopaedic practice. With the advent of new inertial measurement units (IMUs) and computer vision-based tools, we have recently reached the point at which biomechanical analysis is becoming useful in clinical practice. We are now seeing rapid growth in the clinical use of objective, quantitative gait analysis tools for veterinary purposes and for use in training and careful longitudinal monitoring of sports horses. For the first time in history, large databases of equine gait are being developed that open the door to using AI/machine learning techniques that may easily lead to paradigm shifts in how we look at horses. The technology may also be invaluable in addressing the increasing concerns about welfare issues related to equestrian activities and maintaining the horse industry's social license to operate. In the meantime, these novel technologies have also taken off in canine veterinary practice and sports medicine and can be expected to expand further in the future.

The times may be, to a certain extent, challenging and demanding for the use of animals in sports and leisure activities. However, the novel technologies also offer tremendous opportunities. ICEL contributes to the welfare and durable co-existence of both animals and humans by offering a platform for embracing novel technologies and using them in a judicious, critical and scientifically sound way.

The ICEL International Committee

Utrecht University

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International Committee of ICEL9

P. René van Weeren (1957) graduated in 1983 from the Utrecht University Veterinary Faculty (The Netherlands). He became a staff member of the Department of General and Large Animal Surgery in that year and obtained his PhD degree in 1989. From 1991-1993 he worked as a visiting professor at the Escuela de Medicina Veterinaria of the Universidad Nacional in Heredia, Costa Rica. He became a diplomate of the European College of Veterinary Surgeons in 1994. He was appointed as full professor to the Chair of Equine Musculoskeletal Biology in 2007 and is now mainly involved in research with focus areas articular cartilage, tendons and biomechanics and in administration. He became Head of the Department of Equine Sciences of the Faculty of Veterinary Medicine of Utrecht University in 2012 and Head of the Department of Clinical Sciences in 2020 after the restructuration of the Faculty of Veterinary Medicine of that year, involving the merger of the Departments of Equine Sciences and of Clinical Care of Companion Animals and the section of Anatomy and Physiology of the former Department of Pathobiology. René van Weeren has been a supervisor of 39 PhD students, who have obtained their degree in the past years and currently supervises 11 PhD students, who will be graduating within the next few years. He has been an associate editor of Equine Veterinary Journal for many years, was a member of the editorial board of The Veterinary Journal and has been or is a member of the scientific board of several others. He has been guest editor of various Special Issues or Supplements of a variety of scientific journals. He has been external examiner for PhD students abroad at various occasions in Belgium, the UK, France, Austria, Sweden, Norway and Finland. He is author or co-author of more than 350 peer-reviewed scientific publications and has contributed various chapters to a variety of textbooks. He is one of the editors of the 2nd edition of Joint Disease in the Horse. He was a member of the International Committee of the International Conference on Equine Exercise Physiology (ICEEP) from 2010 to 2022, of which he was the Chair from 2014-2018. He is also a member of the International Committee of the International Conference on Canine and Equine Locomotion (ICEL) and was a founding member of the predecessor of this organization, the International Workshop on Animal Locomotion (IWAL).

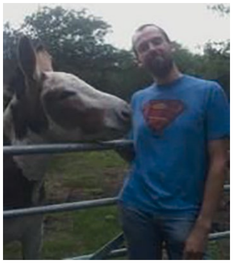
Christian Peham graduated as a communication engineer at the University of Technology Vienna and worked on the Clinic of Orthopaedics in Ungulates at the University of Veterinary Medicine Vienna. He finished his doctoral thesis in 1994. Since 2001 he is associate Professor of Biomechanics at the University of Veterinary Medicine Vienna. He is the head of the Movement Science Group Vienna. Prof. Peham's research focus is in the areas of equine and canine biomechanics. Recently, his research has focussed on development of anatomy-based models of the equine back and neck. He was co-author of 2 books, 2 patents and 90 peer-reviewed manuscripts. Prof. Peham was one of the organizers of the IWAL 2000, EWOMS 2005 ICEL7 and the ICEL8. He has been bestowed by the Bank Austria Science Award.

Nathalie Crevier-Denoix graduated from the Veterinary School of Alfort (France, 1989). Agrégée in Veterinary Anatomy (1993), she defended a PhD thesis in Biomechanics (1996). Professor of Anatomy (1999), she is also (since 2003) the head of a research unit devoted to Biomechanics and equine locomotor pathology in Alfort. After a Veterinary Doctorate on the radiographic images of the limbs of the foal, her research activities have been covering two topics: equine tendon imaging and biomechanics, and biomechanical effects of equestrian surfaces. Her main achievements are the development of a non-invasive device for in vivo tendon force measurement (Tensonics, patented), the development and application of a combined dynamometric and high speed kinematic measurement protocol compatible with equine training conditions, the development of a testing device for equestrian surfaces, mimicking the interaction of an equine forelimb with the ground in the vertical plane (Equine Track Tester, ET2, patent deposited). In 2016 she became diplomate of the ACVSMR, and in 2019, de facto diplomate of the ECVSMR (equine). Since 2019, she is principal investigator of a research program on the rehabilitation of superficial digital flexor tendinopathy in racehorses. She published 60 peer-reviewed articles, and presented more than 90 invited lectures and about 100 short communications in international and national conferences.

Hilary Clayton has performed for almost 50 years innovative research in the areas of equine biomechanics, lameness, rehabilitation, athletic conditioning, and the interaction between rider, tack and horse. She has published 7 books and numerous papers in scientific journals and articles in equestrian publications on these topics. Since retiring from academia in 2014, she has continued to perform collaborative research with colleagues from around the world and to provide educational opportunities for scientists and equestrians.

Dr. Clayton is a charter diplomate and past president of the American College of Veterinary Sports Medicine and Rehabilitation. She is an Honorary Fellow of the International Society for Equitation Science and has been inducted into the Roemer Foundation/USDF Hall of Fame, the International Equine Veterinarians Hall of Fame, the Midwest Dressage Association Hall of Fame and the Saskatoon Sports Hall of Fame. She is a lifelong rider and has competed in many equestrian sports currently focusing on dressage.

Lars Roepstorff graduated as a veterinary surgeon 1985. He has practiced as an equine clinician both in private practice at different clinics and at the Swedish University of Agricultural Sciences (SLU). He has worked closely to equestrian sports with assignment as a national team vet and as a lecturer in continuing education of professional trainers. He has headed the department of Equine Studies at SLU. His scientific work has focused on biomechanical studies of equine locomotion with the overall aim to improve equine health and soundness. In 2011 he became Professor in Equine Functional anatomy and currently he works with applied biomechanics in three different areas; development of tools for objective equine lameness diagnostics, horse-rider interaction and equine footings.



Thilo Pfau moved in September 2021 from Great Britain to join the faculties of Kinesiology and Veterinary Medicine at UCalgary. He is currently developing a lab in Veterinary Medicine. Dr. Pfau has a multidisciplinary research background in animal biomechanics mainly with high performance horses. He combines his expertise in computer science, particularly in data processing and information extraction, and pattern recognition, with extensive experience in research in fundamental and applied locomotor biomechanics.

Michael A. Weishaupt graduated in Veterinary Medicine in 1989 at the University of Berne. Between 1990 and 1993 he worked as an assistant at the Swiss National Stud in Avenches and completed his doctoral thesis on "The relationship among local structural, biochemical and functional variables describing muscle oxidative capacity in horses and steers" at the Department of Large Animal Medicine of the University of Berne. Since fall 1993 he has worked at the Vetsuisse-Faculty of the University of Zurich and is in charge of the Equine Performance Centre, a clinical as well as research division of the Equine Department. His special interests are equine sports medicine and rehabilitation, exercise physiology, diseases of the upper airways, equine orthopaedics, shoeing and biomechanics. In 2004 he finished his PhD on "The compensatory mechanisms of weight bearing lameness in horses". In 2010 he received the Venia legendi of the University of Zurich for Equine Sports Medicine and Exercise Physiology. Dr. Weishaupt is diplomate of the American College of Sports Medicine and Rehabilitation and member of the research committee of the International Conference on Canine and Equine Locomotion (ICEL).

In addition to a number of research papers in the field of sports medicine and biomechanics, he has published as editor two e-learning tools, one on equine upper airway diseases (Equad) and one on shoeing and diseases of the hoof (e-hoof.com). Dr. Weishaupt is an accredited racetrack veterinarian, member of the veterinary advisory board of the Swiss Horseracing Federation, member of the accreditation board of the European Federation of Farriers Associations (EFFA) and founding member of the Sporthorse Welfare Foundation (SWF).

Local Organization Committee of ICEL9

Filipe Serra Bragança was born in 1988 in Portugal. He graduated in 2013, from the Veterinary University of Lisbon. After graduation, he performed his internship at an equine practice in the UK. In late 2014 he started his PhD at Utrecht University (the Netherlands) performing research in biomechanics and equine locomotion, focusing on objective gait analysis. The main goal of his PhD was the further development and clinical implementation of techniques of objective gait analysis and lameness assessment in the horse based on motion-capture and IMU-sensor technology. Currently he is leading the locomotion research team at Utrecht University together with René van Weeren. Current projects: further development of a sensor-based systems for gait and performance analysis, objective assessment of horses with back pain, genetics of gait, development of gait analysis modalities for different gaits (including the gaits of the Icelandic horse), integration and standardization of surface EMG in horses and usage of machine learning techniques to study locomotion.

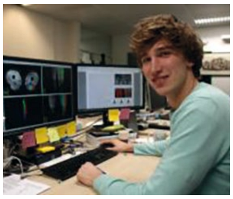
Nikae te Moller (1990) graduated from the Utrecht University Veterinary Faculty (the Netherlands) in 2015. The same year, she was awarded a PhD fellowship by NWO (The Dutch Research Council) at the Department of Equine Sciences in Utrecht and in close collaboration with the University of Eastern Finland. Her focus was on intra-articular imaging of the articular cartilage and investigating biomarkers for early stages of articular cartilage damage, as well as the influence of cartilage damage and exercise on the equine joint. In 2018 she used the UU Public Engagement Seed Fund which she was granted to express her research to the general public through dance. She obtained her PhD degree in December 2019. Currently, Nikae has a part-time position as a postdoctoral researcher in the equine locomotion research team in Utrecht, where she works on kinematic effects of aqua training in horses and on the quantification of facial pain expression. Besides research, she works as an equine sports massage therapist and she enjoys dance, music and sports.

Ineke Smit (1994) graduated from her masters in human movement sciences at the Vrije Universiteit In 2019. Her Bachelor (Rijksuniversiteit Groningen) and Master (Amsterdam Medical Center) research projects focused on evaluating the effects of certain interventions on (the energetic cost of) human locomotion. Here she gained experience in using technologies such as surface electromyography, force plates and optical motion capture in order to grasp different aspects of human movement. Afterwards, she started as a PhD candidate at the faculty of veterinary medicine at Utrecht University in close collaboration with the Swedish agricultural university (SLU). In her research she focusses on adding complexity, in terms of signal processing as well as data collection methods, to the studies of equine locomotion. Her main focus is currently on the application and methodological standardisation of surface electromyography measurements in the horse for both locomotion and pain face quantification purposes.

Jeanne Parmentier (1995) graduated from the University of Compiègne (France) in Biology, Biomechanics and Biomaterials engineering (2018). During her studies, she conducted research on equine and ovine biomechanics, including motion capture, inertial sensors and forceplate analysis. She then worked as a research engineer within the CWD-VetLab (Ecole Nationale Veterinaire d'Alfort) and in collaboration with the CIRALE (France) to develop an inertial sensors-based tool to quantify horses' locomotion. She is currently a PhD candidate from the Utrecht University, Faculty of Veterinary Medicine and the University of Twente, Pervasive Systems group. Her PhD focuses on bringing useful information to vets during locomotion evaluations to improve horse welfare, by combining sensor data (inertial sensors, electromyography, microphone...) and machine/deep learning techniques (e.g., SVM, CNN or LSTM). This information can include locomotion and physiological analyses (heart rate, breathing rate), context detection (e.g., surface), and ultimately (early) lameness detection. Apart from her enthusiasm for data and animal research, Jeanne enjoys horse-riding, food and traveling around the world (best when combined).

Rhana Aarts (1993) obtained her Bachelor's degree in animal Husbandry with a specialization on Equine, Leisure and Sports from VHL University of Applied Sciences (NL) in 2016. As part of this, she completed a minor at Writtle University College (UK) focusing on Equine Science and Equine Sports therapy. In 2019 she graduated from Wageningen University (NL) with a Master's degree in Animal Sciences specializing in Animal Nutrition and Adaptation Physiology. Over the years she conducted research in various animal species (calves, pigs, cats & dogs) and before starting her PhD in 2021, she worked as a researcher in an animal nutrition company. Currently, she is a PhD candidate at the Faculty of Veterinary Medicine at Utrecht University in collaboration with the Swedish University of Agricultural Sciences (SLU). Her research focusses on combining kinematics with physiological parameters, like heart rate and respiration rate, in order to improve equine welfare and performance during training and/or competitions.

Michelle Teunissen (1991) is a veterinarian with a focus on translational research. She started her Bachelor‘s degree in Veterinary Medicine at Utrecht University in 2009. After completing her Bachelor’s degree, Michelle was selected for the Master‘s Honours Program, where she researched growth plate differences in large and small breed dogs under the guidance of Professor Marianna Tryfonidou. During her Master’s studies, she also participated in the Cornell Veterinary Leadership Program at Cornell University in Ithaca, New York in 2016. After completing her Master‘s degree cum laude, Michelle pursued a PhD studying the mechanisms behind joint distraction, where she obtained funding for studies that resulted in the first canine patient being treated with knee joint distraction. She successfully defended her PhD thesis, titled "A Joint Effort: How dogs contribute and benefit from the ’One medicine’ approach to osteoarthritis," in 2022. Michelle’s focus on translational research has led her to continue her career as a post-doctoral researcher at Utrecht University, where she is working on developing in vitro models for osteoarthritis and investigating new methods to evaluate joint pain in dogs.



Joep Suskens (1994) graduated as a human movement scientist at the Faculty of Behavioural and Movement Sciences of the VU Amsterdam in 2018. After his graduation, he started his PhD on hamstring injury prevention among athletes under the supervision of prof. dr. Gino Kerkhoffs, prof. dr. Hans Tol and dr. Guus Reurink at the department of Orthopedic Surgery and Sports Medicine at the Faculty of Medicine of the Amsterdam UMC hospital. Here, he worked with diffusion tensor magnetic resonance imaging (DT-MRI), surface electromyography and motion capture to investigate the effects of injury prevention exercises on hamstring muscle characteristics. While awaiting his PhD defense, Joep continued his career as an academic researcher at the department of Clinical Sciences at the Faculty of Veterinary Medicine of Utrecht University within the field of Equine Musculoskeletal Biology, focusing on the development of reference values for surface electromyography and motion capture application to evaluate horse lameness and rehabilitation progress.

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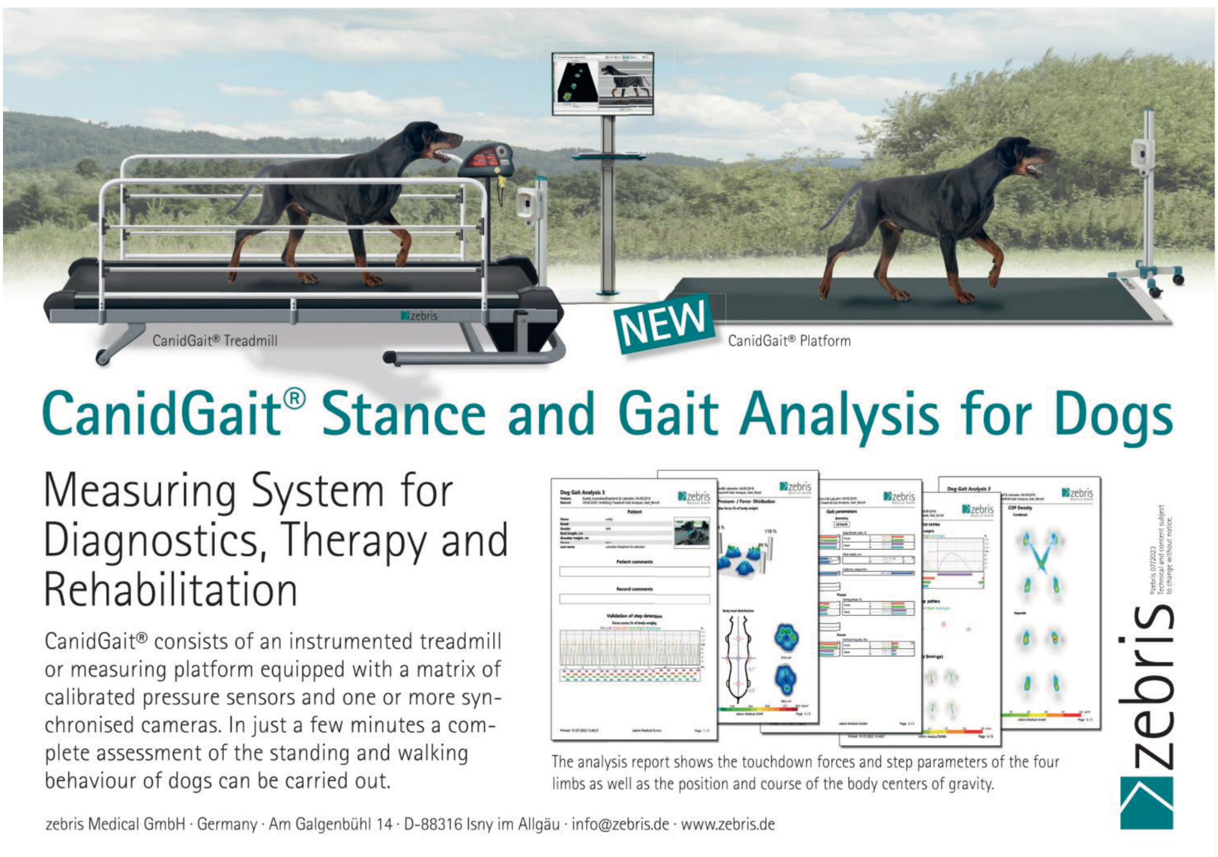

Session 1 – Modelling, Machine Learning

Surface types can be classified with equine IMUs data and machine learning

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Equine orthopaedic gait evaluation is typically performed with inertial measurement units (IMUs) on undeformable hard and deformable soft surfaces (e.g. bricks/sand). Surface types influence locomotion but are rarely noted down, leading to information-loss. This study automatically labels IMUs data with surface types using machine learning (ML) models. Ninety-six horses were measured at walk and trot, straight lines and circles, hard and soft surfaces, at different locations. Six IMUs (200 Hz) were fastened to withers, sacrum and the lateral aspect of each cannon bone. Pre-processed IMUs data (3D gyroscope and accelerometer) were segmented into three-second windows with 50% overlap. Features were extracted (descriptive statistics, time- and frequency-domains), and labelled as Hard or Soft. Nine datasets were created with different IMUs (upper-body, limbs, all) and gait (walk, trot, all) combinations. The 100 most important scaled features (infinite latent feature selection) were used to train and test linear support vector machine (SVM) and 99-splits decision tree (DT). The process was repeated five times with different randomly selected horses (training-test ratio: 60-40%). Surface classifiers were evaluated with mean F1-scores. Overall, SVM performed better than DT (F1: 89%, 83%). SVM using all IMUs, or limbs only outperformed upper-body (F1: 94%, 93%, 79%). Training SVM with pooled gaits or walk or trot only did not affect the performance (F1: 89%, 88%, 89%). These findings show that ML models can reliably discriminate hard/soft surface types from IMUs signals. Automated surface labelling augments the available metadata in equine locomotion databases.

Evaluation of DeepLabCut for markerless tracking of dogs performing agility behaviours

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Canine sporting activities, such as agility, have grown in popularity. Rules differ between different governing organizations, but these differences are not rooted in evidenced-based studies that balance canine performance vs injury risk. Development of (semi)automated markerless motion capture methods of obstacle performance opens options for exploring these relationships. We used DeepLabCut for two different machine learning experiments for dog agility videos, collected at 120 fps on a stationary iPhone (iPhone 14 Pro: 48 MP Main Camera with default settings and 1,920×1,080 resolution): (1) a single dog performing six different agility behaviours; and (2) five different dogs performing the same behaviour, the teeter obstacle. For each experiment, the pre-trained DeepLabCut model was fine-tuned and then evaluated on one of the experimental datasets for the body parts of interest for 380 and 100 frames, respectively. The resultant networks were used to track both the training videos and novel sequences, which were pooled for analysis. Model performance was evaluated over 100 random frames for each network and scored using a binary system for marker accuracy. For the single dog experiment, 87.6% (80-99% accuracy per marker) of marker locations were correctly placed and for the multi-dog experiment 82% (77-93% accuracy per marker) of marker locations were correctly placed. Errors were most commonly incorrectly sided paws. This data demonstrates a promising avenue for markerless motion tracking that, with further refinement, will significantly reduce the manual input necessary. This will allow access to new research questions through access to previously unmanageable-sized datasets to inform decisions on obstacle parameters and minimize injury risk in sporting dogs.

Applying deep learning to IMU data to classify lameness location in horses

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Lameness assessment in horses is challenging and could be improved with gait quantification systems and deep learning. This work evaluated inertial measurement unit (IMU) stride data classification as Sound, Front or Hind lame using convolutional neural network (CNN) and Fourier analysis threshold-based (FA) classifiers. Retrospective data from different unilateral lameness induction studies were used (Shoe, LPS and patellar ligament models). Twenty horses were trotted in a straight line with seven IMU sensors (200 Hz). Vertical displacements of the head (H), withers (W) and sacrum (S) were segmented into strides, then labelled as Sound (baseline), Front or Hind (successful front/hindlimb induction; median absolute Head-Difference-Min: 44 mm and Sacrum-Difference-Min/Max: 19/19 mm respectively). Horses were split into training, cross-validation, and testing sets (14-2-4) for CNN. The same training and test horses were used to define and evaluate the FA thresholds. CNN inputs were H-W-S, H-S or W-S strides, while FA used H-S or W-S. Performances were evaluated with mean F1-score per class (Sound, Front, Hind), over ten different training-(validation)-testing sets. CNN presented higher F1-scores for Sound classification than FA, where $CNN_{H\text{-}W\text{-}S}$ and $CNN_{H\text{-}S}$ performed the best (F1-score: [69,66]%). For Front classification, H-S outperformed W-S for both CNN and FA (F1-score: CNN:[74,49]% vs FA:[74,24]%). FA was not able to classify Hind strides (F1-score<50%), while CNNs had F1-scores>70%. This study shows that using upper-body displacements and CNN, it is possible to classify sound, front and hind strides. Our comparison approach can also aid in understanding which IMU locations are crucial for lameness detection and classification.

Using dynamic time warping for robust and efficient straight trot stride identification

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Stride identification and segmentation is a common step when quantifying horse gait asymmetries and identifying lameness. The goal of this study was to compare stride counts achieved by isolated event detection and warped matching of signal-time sequences. From 25 horses in training that were perceived free from lameness by the riders, a total of 160 different trot in-hand trials were included in this study. An inertial sensor was mounted at the pelvis of horses to measure kinematics during straight trot in-hand. Vertical velocity of the pelvis was high-pass filtered. Reference stride identification was conducted with an adapted event detection method (EQDOT, EQUIGAIT), and the number of strides counted per trial, using pelvis roll to identify left hoof down. A time normalized (100 samples) pelvic vertical velocity template sequence was calculated using the first 25 strides for each horse. Using the mean stride across horses as a template, dynamic time warping (DTW) was applied to pelvis vertical velocity for each trial and strides were counted from the time-warped data. Stride number differences were calculated per trial between reference and DTW. The mean(SD) number of strides identified by reference method was 14.0(7.4) strides (range of 3-38); the mean(SD) number of strides identified with DTW was 27.7(10.7) strides (range: 9-57). On average, the DTW identified 13.7(6.2) more strides, which represents a 97.9 percent increase. DTW presents a robust method for identifying and segmenting trot strides, allowing to accurately extract strides in the presence of stride-to-stride inconsistencies that cause problems in event-based stride segmentation.

Session 2 – Functional Anatomy

Understanding the role of muscle activity on tendon and ligament strain within the equine forelimb

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Of the digital flexor tendons of the equine forelimb, the superficial digital flexor tendon (SDFT) is preferentially injured, affecting up to 13% of racehorses. Forelimb suspension is complex, with both passive and active structures, as well as muscles with different properties. Yet the role of these components in locomotion remains poorly understood. To gain a better understanding, we developed both a whole-limb cadaveric testing system and computer model to predict *in vivo* biomechanics of the forelimb, with a focus on understanding the role of muscle activation/fatigue on the development of pathologic strain within the equine SDFT. The cadaveric system can individually actuate the SDF and DDF muscles while simultaneously cycling the entire limb and measuring resultant strain in the flexor tendons, their associated accessory ligaments, and the suspensory apparatus. Utilising the mechanical advantage of pulleys and ropes, we created a working system capable of applying 3,000 N of vertical force to simulate a trot and forces of 700 and 1,500 N to simulate maximum active isometric contraction force of the SDF and DDF muscles, respectively. Future directions will involve comparing the cadaveric system findings to both in vivo measurements and to a novel 2D computer model which utilizes limb geometry and tissue properties to predict tissue strain, particularly in components unavailable to direct measurement. Preliminary results from parallel computer model validations have reported strains within 5% of those measured on our cadaveric model. Overall, this work will provide relevant understanding of how we may better predict, prevent, and treat equine SDFT injuries.

The effect of the sternum lift and different head and neck positions on thoracolumbar posture

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The sternum lift (StL) exercise aims to raise the sternum and withers within the thoracic sling. This study compared thoracolumbar posture induced by a StL and different head and neck positions (HNPs). Fourteen clinically normal sport horses (163±8 cm) were measured with nose level with shoulder joint (HNP1), carpus (HNP2) and withers (HNP3) and during a StL whilst in HNP1. Skin-fixated markers on spinous processes of T6, T10, T13, T17, L3; mid-tuber sacrale (MTS) and sternum: cranial (S1), mid (S2) and caudal (S3) were tracked with nine motion capture cameras (100 Hz). Differences in dorsoventral displacement of markers and distance T6 to MTS (TLSD) between HNP1-StL, HNP1-HNP2 and HNP1-HNP3 were compared using paired t-tests (significance level $P<0.05$). Relative to HNP1 dorsal displacement was greatest in StL at T10, T13, T17, S1 and S3 (means: +5.61±1.56 cm ($P=0.000$); +6.20±1.65 cm ($P=0.000$); +5.30±1.79 cm ($P=0.000$); +6.05±1.78 cm ($P=0.175$); +5.92±2.44 cm ($P=0.171$); and higher in StL compared to HNP2 in relation to withers height (mean +2.29%, $P=0.001$). In HNP2, there was greatest dorsal movement at T10, T13 and S3 (means: +1.29±1.02 cm ($P=0.001$); +0.96±1.07 cm ($P=0.007$); +1.34±1.45 cm ($P=0.008$), with other markers having ventral movement: T6, S1 and S2 (means: -0.97±1.09 cm ($P=0.007$); -5.48±2.72 cm ($P=0.000$); -1.89±1.50 cm ($P=0.001$)). HNP3 resulted in a mean ventral movement of all spinal markers (-0.22±1.18 cm). HNP2 had a significant longer TLSD (mean: +4.70±1.91 cm) compared to the StL (mean +2.62±1.95 cm) ($P=0.006$). The StL creates dorsal movement of the thoracic sling, while ventral movement occurs when lowering the head. This supports using StL as part of core strengthening exercises for horses.

Racing performance and dorsal spinous process radiographic abnormalities in 265 National Hunt horses

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Radiographic abnormalities of the dorsal spinous processes (DSP) are frequently stated as a cause of poor performance in horses. The objective of this study was to establish if there is a correlation between radiographic abnormalities of the DSP's and poor racing performance in National Hunt horses. The thoracolumbar region of Irish National Hunt Thoroughbred Racehorses (n=265, 178 geldings, 87 mares; age range: 5-16 years, mean = 8.5±1.8, median = 8) in active race training from one training facility in Ireland were radiographed. All radiographs were graded by all 5 independent observers blinded to horse name and performance history for narrowing, sclerosis and lucency (0=normal, 1=mild, 2=abnormal) of the DSP's. Race performance variables were obtained for each horse from the Racing Post website (racingpost.com) and compared to their composite radiographic grades (sum of mean of individual scores) using Pearson's correlation coefficients (alpha=0.05). The average composite score for all horses was mean= 1.48±0.90 (range: 0-3.38), indicating that most horses showed some level of radiographic abnormality, with only 2 horses having no abnormalities of the DSP's. There was no relationship between lifetime earnings (mean = £118,959.3, min = £0, max= £1,583,124.0) and total abnormal spaces averaged across raters ($r(47)=-0.13$, $P=0.38$), nor between abnormal spaces and racing post rating ($r(47)=-0.10$, $P=0.51$). There were no sex differences for any of the measures ($P>0.05$). Radiographic abnormalities of DSP's of National Hunt horses in race training are not significantly associated with poor racing performance.

Differences in gait quality parameters between Franches-Montagnes and Swiss Warmblood horses

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Gait quality is an important selection criterion in many European horse breeds, but is usually evaluated subjectively. The aim was to compare the objective gait quality parameters speed, stride length, maximal protraction (A_{prot}) and retraction (A_{ret}) angles of the fore and hind limbs and suspension duration (SpD) of two Swiss horse breeds. We measured 157 Franches-Montagnes (FM) and 40 Warmblood (WB) horses at three years old with the EquiMoves® system at walk and trot. Speed was recorded with Freelap®. Differences due to breed, sex and breed × sex interactions were analysed using a linear model approach. WB walked faster (1.73±0.07 vs 1.66±0.11 m/s; P<0.0001), with longer strides (1.99±0.11 vs 1.77±0.12 m; P<0.0001) as they were taller (1.65±0.05 vs 1.56±0.03 m). WB had larger A_{prot} of the fore- (34.51±1.52 vs 32.42±2.38; P<0.0001) and hindlimbs (28.51±1.82 vs 27.60±2.11; P<0.05), FM had greater forelimb A_{ret} (41.68±3.02 vs 38.65±3.00; P<0.0001) at walk. At trot, WB had the longer strides (3.27±0.34 vs 2.96±0.29; P<0.0001). FM had greater forelimb A_{prot} (27.59±3.21 vs 24.86±3.34; P<0.01) and hindlimb A_{ret} (24.88±3.13 vs 23.62±3.84; P<0.01). SpD for FM was longer compared to WB (0.039±0.026 vs 0.006±0.030 s; P<0.0001) which was surprising as WB horses are considered the better sport horses. WB showed more limb movement and longer strides at walk, FM had shorter strides but showed more limb movement at trot. Correcting for size and speed should improve our understanding of breed-specific differences.

Differences in joint angles from photographs between six European breeds – preliminary results

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Horse breeds are expected to show differences in their conformation traits due to selection for specific uses and aesthetics. However, these differences have seldom been compared objectively, as each breed is evaluated subjectively by their own judges. Therefore, joint angles were extracted from standardised photographs from the side at stance of 888 horses of six different breeds: 529 Franches-Montagnes (FM), 73 Warmblood (WB), 28 Purebred Arabians (AR), 32 Shagya Arabians (SHA), 228 Lipizzaner (LIP) and 19 Pura Raza Español (PRE) horses. Landmark placement was based on the horse shape space model consisting of 246 2D landmarks. The angles were compared between breeds using ANOVA and Tukey Honest Difference tests (P<0.05). The poll angle was larger (more open throat) in lighter horses (AR=106.30±5.51, SHA=104.76±4.14, WB=106.93±6.55) than in FM=103.25±5.24, LIP=103.12±4.94 and PRE=102.62±5.59. FM and AR were rather buck-kneed (larger carpus angle, >179°), while LIP and PRE were more calf-kneed (<179°). The FM also had straighter hind fetlock angles (>154°) than the other breeds. As expected, AR and SHA had a larger hip angle (more horizontal croup, >80°). The hock angle did not differ between breeds. This dataset is a promising first step to evaluate breed-specific differences in conformation using a consistent method, but more data is needed in breeds with lower sample size. This data should be compared to dynamic conformational data and finally to movement patterns, to understand its functional significance, as well as to genomic data in genetic studies.

Session 3 – Muscle, EMG

Effects of incline on muscle activity of hind limb during canter on a treadmill

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This study aimed to investigate the effects of incline on surface hind-limb muscle activities during canter. Seven Thoroughbreds (528±62 kg, mean ± s.d.) equipped with hoof strain-guages were used for the recording of surface electromyopraphy of the M. tensor fasciae latae (TFL), M. gluteus medius (GM), M. biceps femoris (BF), M.semitendinosus (ST), M. extensor digitorum longus (EDL) and M. deep digital flexor (DDF). Surface electrodes and strain gauges were attached to the leading limb side during canter. Data were collected at 1000 Hz with a 30-500 Hz bandpass filter. Horses cantered at 10 m/s on a treadmill at inclined -4, 0, 4 and 8% randomly for 30-s each without lead change. The averages of ten consecutive stride durations, stance times, and integrated-electromyograpchic values (iEMG) for a stride were compared using one-way repeated ANOVA followed by Tukey's post hoc test (P<0.05). Stride duration significantly decreased with incline and was the shortest at 8% (-4%; 505±20, 0%; 502±15, 4%; 497±17, 8%; 487±16 ms, P<0.01), while no changes were detected in stance time (137±9, 136±8, 137±8, 135±9 ms, respectively). The iEMG in GM, BF and ST at 8% incline was significantly higher than other conditions (+45, +37 and +58% increase compared with 0%, respectively), while no incline effects were found in TFL, EDL, DDF. Training on steep incline could increase muscle activity in hip joint extensor muscles, which are essential for high-speed galloping.

How different skin preparation methods affect surface electromyographic measurements in the horse

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Skin preparation is paramount for surface electromyographic (sEMG) signal quality and subsequent measurement results. However, no standardised skin preparation procedures for animals have been reported. In our study, four skin preparation procedures for measurements using sEMG in horses were compared and evaluated. Five muscles (longissimus dorsi, semitendinosus, triceps brachi caput longum, ulnaris lateralis and gluteus medius) of five warmblood horses were measured under four skin preparation conditions each. These conditions were: (1) no preparation (hair length ±5 mm); (2) cleaned (ethanol 80%); (3). clipped (1 mm) and cleaned; and (4) shaved and cleaned. Electromyographic data were collected (TMSi SAGA, 4,000 Hz, bipolar configuration, pregelled Ag/AgCl electrodes) for 60 seconds at trot (12.5 km/h, treadmill) for each condition. Input impedance, root mean square (RMS) and signal-to-noise ratio (SNR) were compared using linear mixed models (fixed effect='condition', random effect='horse' and covariate='muscle'). No contact was achieved (invalid input impedance values) in 25/25 'no preparation' and 19/25 'cleaned' conditions. Qualitatively, the remaining six 'cleaned' trials showed unrealistically high raw signal values and did not resemble equine muscle activation patterns. All trials for conditions 1 and 2 were thus removed from quantitative analysis. Differences in estimated marginal means between 'clipped' and 'shaved' were -0.4 kΩ (P=0.03), 0.1 μV, and 1.4 dB for input impedance, RMS and SNR, respectively. The results demonstrate that without hair removal, sEMG signal quality is very poor and does not resemble the muscle activation pattern in horses, which will lead to unreliable study outcomes. In addition, the differences between clipping and shaving, both combined with cleaning, are neglectable.

Which sEMG variable best distinguishes between non-lame and induced lameness conditions in horses?

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This study aims to determine the most effective surface electromyography (sEMG) measure, from individual muscles, for distinguishing between non-lame and induced fore- (iFL) and hindlimb (iHL) lameness conditions. We compared bilateral sEMG absolute value and asymmetry measures from triceps brachii (triceps), latissimus dorsi, longissimus dorsi (longissimus), biceps femoris (biceps), superficial gluteal (gluteal) and semitendinosus. sEMG and 3D-kinematic data were collected from n=8 clinically non-lame horses during in-hand trot. iFL and iHL were induced on separate days using a modified horseshoe, with baseline data initially collected each day. MinDiff was calculated from poll (HDMin) and pelvis (PDMin) vertical displacement. sEMG signals were DC-offset removed, high-pass filtered (40 Hz), and full-wave rectified. Average rectified value (ARV) was calculated per stride and normalised to the maximum observed value of individual muscles at baseline (sEMGabs). The difference between right and left normalised ARV were calculated per muscle and stride (sEMGasym). Receiver operating characteristic analysis was conducted, using area under the curve (AUC) as an overall measure of discrimination between baseline and iFL/iHL. MinDiff showed excellent discrimination for iFL (HDMin AUC=0.98) and iHL (PDMin AUC=0.96). Triceps sEMGasym was best (AUC=0.84) for differentiating iFL, with other measures showing fair to chance discrimination (AUC range=0.49-0.76). Lame-side gluteal, semitendinosus and longissimus sEMGabs (AUC range=0.90-0.91) showed excellent discrimination for iHL, followed by biceps sEMGasym (AUC=0.83). Evidently, the choice of sEMG variable is muscle/condition dependent: sEMGabs performed acceptably across muscles/conditions, but triceps and biceps sEMGasym, respectively, appear superior for discriminating iFL and iHL.

Longissimus dorsi muscle activity in sound horses during in-hand trot on a straight line and circle

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The objective was to examine and compare muscle activity of the longissimus dorsi muscle in sound horses during in-hand trot on a straight line and circle to understand muscle activity distribution under normal conditions. Five sound horses performed three trials in trot on a hard surface: straight-line in-hand (4×25 m) and lunging on the left and right circle. Bipolar surface electromyography (2,000 Hz) described bilateral longissimus dorsi muscle activity at T16. Wireless inertial sensors (200 Hz) were used to detect locomotion asymmetry and perform stride normalization (hind foot impact of the corresponding side). Twenty strides were extracted after frequency filtering; 40 Hz high-pass, 450 Hz low-pass, 25 Hz low-pass over linear-envelope. Signal amplitudes were normalized to the median peak value during the straight-line trial. Statistical parametric mapping was used (two-way ANOVA) to analyse the level of muscle activity between conditions (straight-line, inside-circle, outside-circle) and anatomical side (left, right) within individual horses. Two distinct bursts of normalized muscle activity occurred in all horses: the first burst between ±20-45% and the second between ±70-95% of the stride cycle. On the straight line, muscle activity was significantly higher compared to the inside- and outside-circle. Muscle activity on the inside-circle was significantly higher compared to the outside-circle during the first burst. During the second burst, muscle activity on the straight-line was significantly higher compared to the outside-circle. Different levels of muscle activity of the longissimus dorsi occurred between straight-line and circles during trot. This might have clinical implications for the aetiology, rehabilitation and quantification of equine back pain and lameness.

Mediolateral hock motion: relationship with pelvic symmetry and hindlimb muscle development

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Excessive mediolateral (ML) hock range of motion (ROM) has been linked to pathology or hindlimb muscle weakness. The study aimed to investigate the relationship between ML hock ROM, muscle development (MD) and pelvic symmetry (PS) at walk and trot in competition horses. Twelve horses (13±4 years) with no known history of hock pathology walked (1.5±0.1 m/s) and trotted (3.2±0.1 m/s) on a high-speed treadmill. Optical motion capture (240 Hz) determined ML hock ROM in walk and trot via a caudal calcaneus marker. PS was calculated via min diff/max diff of tubera sacrale. An ACPAT physiotherapist assigned MD scores for gluteus medius (GM)/biceps femoris (BF)/semitendinosus (ST)/semimembranosus (SM) and gracilis (GR) (muscle scores obtained for eleven horses). A paired t-test compared ML hock ROM between walk and trot. Pearson's/Spearman's tested for associations between ML hock ROM, PS and MD scores ($P<0.05$). Walk had greater ML hock ROM (66±13 mm) than trot (31±6 mm)($P<0.001$). PS showed no association with ML hock ROM at walk or trot ($P>0.05$). A lower BF MD score was associated with greater ML ROM of the contralateral hock in walk (left: $P=0.037$/right: $P=0.038$). For right hock, lower MD scores for left ST ($P=0.020$) and SM ($P=0.033$) were associated with increased ML hock ROM but no differences were seen for left hock ($P>0.05$). No relationships were significant in trot ($P>0.05$). Hock ML ROM was not associated with PS but may indicate less contralateral hamstring MD. ML hock ROM is greater in walk than trot, therefore walk appears to be preferable for assessing ML hock ROM, when using calcaneus as a reference point.

Comparison of muscle activity during trotting on different surface types

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This study aimed to investigate the effect of different types of surfaces on the muscle activity of horses during trotting. In a randomized design, 6 Thoroughbreds (3 geldings, 3 females; age, 3-7 years; body weight, 550±19 (mean±SD) kg) trotted on the treadmill, turf, or dirt, on the same day. Stride parameters were detected from high-speed cameras. Muscle activities of the M. infraspinatus, deltoid, longissimus dorsi, trapezius, triceps brachii, ulnaris lateralis, common digital extensor, extensor carpi radialis, gluteus medius, biceps femoris, tensor fasciae latae, extensor digitorum longus, and deep digital flexor were measured using surface electromyography (sEMG; sampling frequency, 2,000 Hz). Electrodes were attached to the centre of the muscle venter, and they were not removed until the end of the experiment. The sEMG data were high-pass filtered (30 Hz) and full-wave rectified, and the average amplitude of a stride was calculated. The effects of surfaces were analysed by mixed models ($P<0.05$). The mean speed of trotting on the treadmill, turf, and dirt was 3.20±0 m/s, 3.17±0.07 m/s, and 3.24±0.06 m/s, respectively. While stride lengths did not show significant differences between surfaces ($P=0.16$), stride frequency on the treadmill (1.48±0.10 strides/s) was higher than on turf (1.39±0.04 strides/s). The average amplitude of the M.common digital extensor was higher on the treadmill (9.13±2.51 μV) than on dirt (5.51±1.14 μV). However, the amplitude of other muscles did not show significant differences. Our results indicate that differences in surface type affect stride frequency and the activity of some muscles during trotting, but not stride length.

Is sEMG a repeatable measure of muscle activity in horses – between-day repeatability at in-hand trot

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The repeatability of surface electromyography (sEMG) is an important consideration for its potential clinical application in equine gait analysis. We hypothesize that equine sEMG profiles are repeatable between measurement sessions, but this has not been demonstrated. Thus, we evaluated the between-day repeatability of normalised sEMG activity profiles, from triceps brachii (triceps), latissimus dorsi (latissimus), longissimus dorsi (longissimus), biceps femoris (biceps), superficial gluteal (gluteal) and semitendinosus in n=8 clinically non-lame horses. sEMG sensors (Trigno, Delsys Inc.) were bilaterally located on muscles to collect data during in-hand trot on two occasions (day 1: 3.11±0.23 m/s, day 2: 3.07±0.35 m/s) with a minimum 24-hour interval. Raw sEMG signals from ten trot strides per horse and day were DC-offset removed, high-pass filtered (40 Hz), full-wave rectified, low-pass filtered (25 Hz), and normalised with respect to peak amplitude and percent stride. Within-subject, ensemble average sEMG profiles across strides from each muscle and day were calculated. The adjusted coefficient of multiple correlation (CMC) was used to evaluate the between-day repeatability of ensemble average sEMG profiles and tends to 1 when waveforms are similar. Bilateral gluteal, semitendinosus, triceps and longissimus (at T14 and L1) and left biceps showed excellent between-day repeatability with group-averaged CMCs>0.90 (range 0.90-0.97). Bilateral latissimus and right biceps showed good reliability with group-averaged CMCs>0.75 (range 0.78-0.88). The sEMG profiles studied here are consistent across days, suggesting that it is reasonable to use sEMG to objectively monitor the activity of these muscles across multiple gait evaluation sessions at trot.

Session 4 – Fundamentals of Locomotion

A pilot study evaluating the kinetics of dogs during work

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Millions of dogs participate in athletic competitions yearly, with high rates of injury. Sled dog injury rates exceed 35%. Understanding the effects of work on the biomechanics of gait is a first step in developing training programs to prevent injury. Our aim was to assess how pulling a load alters the kinetics of gait in sled dogs. We hypothesized they would recruit the hindlimbs to produce increased force needed for locomotion under increased load. Sled dogs from a single training facility competing in the Iditarod were trotted on a pressure sensitive walkway pulling variable amounts of horizontal tension (load) created with a custom 3:1 pulley system (0 vs 4.1 kg load). Data was assessed for normality and evaluated with a one-way repeated measures ANOVA and Tukey's multiple comparison test for post-hoc pairwise comparisons. Twelve dogs were enrolled with university approval and owner consent. Swing time was decreased in the forelimbs and hindlimbs when pulling 0 vs 4.1 kg of load (P=0.04 and P<0.0001 respectively), but only had a concurrent increase in stance time for the hindlimb (P<0.0001). The stance time front/hind ratio decreased with increasing load (P<0.0001). Dogs selectively recruited their hindlimbs to provide the needed additional force for locomotion while working rather than increasing pulling force with their forelimbs. Future studies should evaluate kinematic data in addition to kinetic data to better understand adaptations on specific joints. Understanding gait changes with work is a first step towards improving training of working dogs and to prevent injury.

Back motion is largely passive in sound horses at walk

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Horses are often presented to veterinarians with complaints of back problems, despite the 'normal' biomechanics of the trunk being poorly understood. This study compared both segmented (thoracic/lumbar) and whole-back (withers-to-sacrum) motion as well as muscle activity between walk and trot. Five owner-sound horses were measured in-hand at walk and trot (straight line, hard surface). Three-dimensional kinematics from the thoracolumbar vertebrae and pelvis (200 Hz), and bilateral surface electromyography (2,000 Hz) from the longissimus dorsi (at T16) and rectus abdominus (cranial of the umbilicus) were captured simultaneously. Range of motion (ROM) and amplitude normalised average rectified values (ARV) were statistically evaluated using linear mixed models (20 strides/horse, random effect='horse', fixed effect ='gait', α=0.05). The whole-back $ROM_{flexion\text{-}extension}$ was larger at trot compared to walk (6.4° vs 4.3°, $P<0.01$). The opposite was true for the thoracic (4.9° vs 6.8°, $P<0.01$) and lumbar (6.0° vs 7.2°, $P<0.01$) segments. $ROM_{lateral\ bending}$ was smaller at trot compared to walk for the whole-back (8.4° vs 12.5°, $P<0.01$), thoracic (7.4° vs 10.0°, $P<0.01$) and lumbar (9.7° vs 10.9°, $P<0.01$) segments. There was no difference between left and right longissimus dorsi, nor rectus abdominus ARVs and ARVs were significantly ($P<0.01$) higher at trot ($ARV_{longissimus\ dorsi}$=27.1 and $ARV_{rectus\ abdominus}$=16.9) compared to walk ($ARV_{longissimus\ dorsi}$=10.2 and $ARV_{rectus\ abdominus}$=3.8). Horses show larger segmented back ROM at walk compared to trot despite much lower muscle activity of both the longissimus dorsi and rectus abdominus. This study suggests that trunk motion is largely passive at walk. Furthermore, whole-back motion does not represent thoracic and lumbar motion.

Gait characteristics in a free ranging dog from a GPS-accelerometer: proof of concept

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Quadrupeds select a limited number of footfall patterns. 'Simple' methods for characterizing gaits may improve our understanding of gait selection. Global positioning systems (GPS) provide speed and location data; additional factors, trajectory incline or curvature and signal periods per second can be calculated. We provide proof-of-concept that a 25 Hz GPS/inertial measurement unit (IMU) (RaceBox Mini) paired with a validated analysis method provides important characteristics from a free-ranging dog. GPS/IMU sensor and iPhone8 (data logging) were attached to the harness of a border collie dog (female, 4 years, 18 kg) during an 18-minute 3-km off-lead bike ride. Power spectrogram maxima of vertical acceleration data (100-sample Hamming window, 2048-Fast Fourier Transformation (FTT)) were identified, and maximum frequency and GPS speed used to calculate speed-frequency-length triads. Plots showed two distinct clusters separated with a frequency-threshold of approximately 3.5 Hz (N1=7,073: speed: 1-4.44 m/s; N2=10,762: speed: 1-11.4 m/s). Linear fit slopes of speed-length clusters were 0.13 (cluster1) and 0.33 (cluster2) representing increases of 13 cm respectively 33 cm per 1 m/s speed increase. Speed together with calculated frequency and length (cluster1: approximately 0.2-0.7 m; cluster2: approximately 0.4-3.5 m) suggest the clusters correspond to trot (speed-step length-step frequency) and canter/gallop (speed-stride length-stride frequency). We have provided proof-of-concept that a 'simple' GPS-IMU-FFT signal processing method is suitable for extracting fundamental gait characteristics in free-ranging medium sized dogs – validation for smaller dogs with shorter legs (higher frequencies) is required. The Shannon-Nyquist theorem and the signal frequency maxima of up to 6 Hz indicate that GPS/IMU sampling frequencies of >12 Hz are required for the presented method.

Differences in racing Thoroughbred movement asymmetries based on racing and training direction

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Racehorses commonly train and race in one direction, which may result in gait asymmetries. This study aimed to quantify gait symmetry in two cohorts of Thoroughbreds that differed in training and racing direction; we hypothesized that there would be significant differences in the direction of asymmetry between cohorts. 307 Thoroughbreds in race training were included: 156 from the anticlockwise Singapore Turf Club (STC), 151 from the clockwise Hong Kong Jockey Club (HKJC). Horses were assessed trotting in a straight line in hand on a firm surface. Inertial sensors were mounted on the pelvis and head to quantify differences between vertical displacement minima (MinDiff), maxima (MaxDiff) and upward (UpDiff) amplitudes, and hip hike difference (HHD). Presence and direction of asymmetry, identified as displacement ≥5 mm, was assessed for each variable. Chi-Squared tests were conducted to identify differences in the number of horses with left or right sided movement asymmetry between cohorts, while mixed model analyses evaluated differences in the values of each variable. HKJC had significantly more horses with left forelimb asymmetry (Head: MinDff $P<0.0001$, MaxDiff $P<0.03$, UpDiff $P<0.01$) compared to STC. There was a significant difference in Pelvis MinDiff ($P=0.010$) and UpDiff ($P=0.021$), as well Head MinDiff ($P=0.006$) and UpDiff ($P=0.017$) between the cohorts. For all significant differences, HKJC mean values were negative (left asymmetry), and STC mean values were positive (right asymmetry). Significant differences in fore- and hindlimb asymmetry between cohorts suggests that horses may adapt gait to racing direction, with movement patterns that reflect reduced loading of the 'outside' limbs.

The effect of trotting speed on upper-body motion in Standardbred warmblood trotters

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In horses, upper-body motion symmetries at trot provide information regarding possible abnormal motion patterns or even lameness. Although difficult to observe at high speeds, knowledge on these motion symmetries is essential to ensure welfare and performance. Therefore, we aimed to describe upper-body motion in trainer-sound trotters driven on the track. Twelve Standardbred warmblood trotters were measured on straight lines during an incremental exercise test. Kinematic data were collected using nine wireless inertial measurement units (ProMove-mini, 200 Hz) attached to the head, withers, tuber sacrale, tuber coxae, and the cannon bones' mid-lateral aspect. Statistical analysis was performed using Linear Mixed Models (fixed-effect = 'speed', random-effect = 'horse', $\alpha=0.05$). Speed during the jog was 5.4±0.2 m/s compared to 10.8±0.2 m/s in the high-speed trot. There were no significant changes in head, withers and sacrum range of motion (ROM) during the high-speed trot vs jog. However, pelvic roll was significantly increased during the high-speed trot, as seen by the increased vertical ROM of the left and right tuber coxae (16.6%; $P=0.04$ resp. 19.8%; $P=0.04$). Although not significant, the head showed an absolute increase during high-speed trot in MinDiff of 7.5 mm to 11.6 mm and decrease in MaxDiff of 11.7 to 7.8 mm. The sacrum showed a large, but not significant absolute increase in MinDiff from 8.7 to 17.0 mm and MaxDiff from 6.9 to 13.6 mm during the high-speed trot. In this study, upper-body ROM at jog was within lameness thresholds and appeared not to be affected by increasing speed with the exception of an increase in tuber coxae ROM.

A comparison of limb kinematics between jog and high-speed trot in Standardbred trotters

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Standardbred trotters have the unique ability to reach and maintain high speeds at trot. A distinct widening of the hindlimbs is reported, but the kinematic profile of the limbs at high-speed trot compared to the jog is not well described. This study aimed to describe the difference in limb kinematic parameters during a jog or slow trot, and high-speed trot. Twelve Standardbred warmblood trotters were measured on an oval track (excluding turns) during an incremental exercise test. Data were collected using nine wireless inertial measurement units (ProMove-mini, 200 Hz) attached to the head, withers, tuber sacrale, tuber coxae, and the cannon bones' mid-lateral aspect. Left/right limb data were averaged into front/hind limb. Statistical analysis was performed using Linear Mixed Models (fixed-effect = 'speed', random-effect = 'horse', α=0.05). Kinematic changes were found when comparing the jog (5.4±0.2 m/s) to the high-speed trot (10.8±0.2 m/s). The increase in speed resulted in a 56.7% increase in stride length (P<0.01) and a decrease of 20.8% in stride duration (P<0.01). Pro-/retraction range of motion (ROM) increased with 67.1 and 46.7% (P<0.01) for the front limbs and hind limbs. Ab-/adduction ROM showed a larger increase for the hind limbs (80.2%; P<0.01) compared to the front limbs (54.0%; P<0.01) in the high-speed trot. Additionally, both maximal hindlimb ad- and abduction increased with increasing speed (7.4° resp. 5.9°; P<0.01). These results improve our understanding of alterations in limb kinematic in trotters to achieve higher speeds and show apparent differences between front- and hindlimb strategies.

Use of IMU-sensors to assess the immediate effects of physiological horseshoeing on the locomotion

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Physiological shoeing in 30 horses without signs of lameness (AAEP scale) (9.7±3.8 years) was assessed using inertial measurement unit (IMU) sensors. Horses were evaluated before (T0) and after (T1) shoeing, and all had last been shoed 35 days before T0. Physiological shoeing consisted in hoof trimming, respecting natural conformation, and application of steel shoes with two clips and a rolled toe. At T0 and T1 Black Werkman Lite© (Black Werkman© V2.0.3) sensors were applied to the dorsal wall of right (RFL) and left (LFL) front limbs› hoofs to assess the duration (ms) of landing, midstance, breakover, swing and stride at walk and trot. Means were compared using the paired t-test (P≤0.05) (IBM SPSS® Statistics). A percentual decrease (T0 to T1) was observed at walk and trot in all parameters except landing at walk in the LFL. Significant differences between T0 and T1 were observed at walk in RFL at midstance (P=0.027), breakover (P=0.015) and in LFL at midstance (P=0.006). At trot a difference between means was observed in RFL in breakover (P=0.007) and landing (P=0.005), and in LFL at midstance (P=0.007), breakover (P=0.04) and swing (P=0.007). Stride was also significantly reduced at walk (P<0.001) and trot (P<0.001) in T1. One limitation of this work was lack of an objective method to assess lameness status. Physiological shoeing may influence duration of stride and its' phases and IMU sensors may be useful for assessing immediate effects of shoeing. Further research is needed to determine long-term effects.

Motion analysis of show jumping horses during jumping over single vertical fences

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One challenge in jumps over vertical obstacles is to redirect a high horizontal approach velocity into a sufficiently high vertical component during take-off. In order to analyse horses' jumping skills in that respect, we analysed kinematics of horses' centre of mass (CoM). We studied 31 jumps of five horses of different education levels (quantified by their highest successful national competition class L(1), M*(1), M**(1) and S*(2)) over single vertical fences (1.30 m height) in training. The horses were ridden by their constant rider. Calculation of 3D trajectories of CoM was based on a model by Buchner et al. Raw data were the positions of 30 markers attached to the horses, recorded by a motion capture system (Vicon, 14 MX3 cameras, 100 Hz sampling frequency). The overall movement pattern showed a lowering of the CoM at the end of the approach. CoM speed at beginning of take-off was v_{total}=5.20±0.32 m/s, whereby the vertical component was $v_{vertical}$=0.20±0.15 m/s. In the take-off phase, hindlimbs push off increased horses´ CoM velocity to v_{total}=5.41±0.37 m/s and the vertical part grew to $v_{vertical}$=1.91±0.23 m/s. Correlations (Spearman's rho) between the education level and the kinematics of the CoM were analysed. Results show that better educated horses achieved higher velocities (v_{total}) at the beginning of take-off (rho=0.975; *P*<0.01) and left the ground with a smaller angle (rho=-0.975; *P*<0.01). Additionally, the CoM-height at take-off tended to be smaller (rho=-0.821; *P*=0.08). Better horses showed a flatter take-off with less loss of movement speed in take-off preparation.

Back angles of the unridden horse on the circle – in walk, trot and canter

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Knowledge of spinal motion on the circle may be useful to riders, veterinarians and physiotherapists. This study aimed to quantify range of motion (ROM) and stride mean for neck, back and pelvic angles, in unridden horses walking, trotting and cantering on the circle. Sixteen horses of varying breeds were lunged (9 m circle) in both directions on soft surface. Mean speed was 1.2 m/s in walk, 2.4 m/s in trot and 3.7 m/s in canter (≥6 strides per trial). Positions of markers at the poll, withers, 15th thoracic vertebra, lumbosacral joint, tubera coxae, and hindlimb cannons were registered using optical motion capture (150 Hz). Stride data were analysed in mixed models (alpha 0.05). The head was positioned more to the inside relative to the body at faster gaits (walk 9-10° [SD 5]< trot 12° [7] <canter 16-17° [7-9]). Mean pelvic roll was near zero in walk, but indicated lean into the circle in trot (5-6° [3-4]) and canter (16° [4-5]). The thoracolumbar back was bent towards the inside in all gaits (5-6° [≤4]). The back was more extended at canter (left/right -21.0 [4.5]/-20.9° [4.1]) than at walk (-21.7 [3.6]/-21.4° [3.7]) or trot (-20.5 [4.0]/-20.7° [3.9]). Back flexion-extension ROM was smallest in walk (4° [<0.9]), while back lateral bending (12° [2]), pelvic roll (10° [2-3]) and yaw ROM (9° [1-2]) were largest in walk. Findings suggest that neck and back motion on the circle reflect an interaction between the constraints of circular movement, and the mechanics of each gait.

Quantifying back movement during sternal and croup reflexes using mounted inertial measurements unit

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Sternal and croup reflexes are used in practice as a therapeutic intervention and assessment tool. Quantification of these reflexes to evaluate movement patterns between back regions and support their application within rehabilitation programmes. The aim was to quantify pitch range of motion (ROM) and direction (positive/nose-up or negative/nose down) of the thoracolumbosacral (TLS) region during a sternal/croup reflex (SR/CR). Twelve horses (11±5.6 years) were recruited with no known clinical history of back injury/dysfunction. Skin mounted inertial measurement units (100 Hz) were placed at thoracic(T)6, T13, Lumbar(L)2, Sacral(S)3 vertebrae. Horses stood square on a flat level surface with a neutral head and neck position. A chartered physiotherapist carried out all SR and CR with three repeats. One complete reflex per horse were included in the analysis. TLS pitch ROM for SR and CR were analysed using paired t-tests (significance set at $P<0.05$). At T6, pitch ROM was greater during SR (6.53±2.8°) compared to CR (4.01±2.7°; $P=0.022$). CR induced greater pitch ROM at T13 (SR: 2.63±1.3°; CR: 4.98±1.9°; $P=0.004$) and S3 (SR:1.91±0.8°; CR:7.89±2.3°; $P<0.001$) compared to SR. No differences at L2 (SR:3.87±2.1°; CR: 4.36±2.9°; $P\geq0.05$) were observed.SR induced positive pitch at T6 and negative pitch at T13, L2 and S3, but CR induced negative pitch at T6 and T13 and positive pitch at L2 and S3. TLS pitch is influenced differently by a SR and CR, with the SR having a greater influence on the cranial/mid-thoracic and CR on the caudal thoracic/lumbosacral spine. The findings have implications on exercise selection within rehabilitation programmes.

Development of a toolbox suite to analyse the kinematics of horse limbs during swimming

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Swimming has been used for over four decades to help maintain a good musculature in horses with tendon and ligament injuries. Despite the clinical advantages of swimming pool training, which reduces stress on the joints, the biomechanics of horse swimming is still not fully understood. In this study, two measurement systems are used to characterize the swimming of 4 horses (to date). The first is a motion capture system consisting of 6 underwater cameras and 28 markers on the horse (7 for each limb), allowing to calculate the joint angles from the shoulder and hip until the 4 fetlocks during the swim. The second is a set of 9 inertial measurement units (IMUs) placed on the head, the sternum, the withers, the 18th thoracic vertebrae, the tuber sacrale and the 4 cannons, which follow the translational movement and angular displacement of these body parts. Four of those IMUs were placed with skin markers on the cannons, providing a basis for comparing the two methods. The 3D data produced by the motion capture system allow to compute the different joint movements on 96 records (to date). Preliminary results (on a single record to date) give the following joint range of motion: shoulder: 100-125°, hip: 60-120°, elbow and stifle: 50-150°, carpus: 50-200°, tarsus: 40-170°, front and hind fetlock:100-180°. In conclusion, this study is one of the first to validate the technological feasibility of 3D motion capture of horse swimming.

Dynamic effect of water levels on the recovery spine movement pattern in horses with kissing spine

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Kinematic of equine back in this work reports the effect of a 4-week back rehab protocol, using water treadmill exercises, in recovery of two report cases with 'kissing spines' between T12-L6.All horses were introduced to aquatic training before data collection. Throughout the hydrotherapy, a biomechanical analysis was used to provide a quantitative assessment of movements once a week. Animals were evaluated at four reference water levels (0, 10-15, 25-30 and 35-40 cm) during walk(4.5 km/h), after 5 minutes of warm up, constant speed for each horse. Kinematic analysis was performed using a 2D model, and analysed variables included axial rotation(AR), pelvic flexion/extension(PFE), maximum flexion amplitude of left hindlimb(FHL), duration of swing phase (SP).Five reflective markers were placed by the same operator using double-sided tape on lateral malleolus of tibia, Ccy1, sacral and left/right coxal tuberosity. Tracking points of each variable were performed in X and Y axes, using Matlab programming platform. During the water treadmill sessions, we could observe an maximal amplitude FHL that promoted an improvement in AR and PF amplitude directly proportional to water levels up to 35 cm.Water levels effectively allowed an increase in hindlimb flexion amplitude that promoted the improvement of all back variables on studied cases. Evaluation of back pattern provides an effective analysis to guarantee a more functional movement in water training recovery.

Session 5 – Sports Applications

Effect of jump height on kinetics at take-off in agility dogs

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On behalf of welfare of agility dogs, the study evaluated the effect of jump height on the kinetics during take-off. Fifteen Border Collies (wither height 46-56 cm) performed bar jumps in a straight-line at 80, 100 and 120% of the dogs' height. Impulses of fore- and hindlimb (FL/HL) pairs were calculated from forces measured by two force plates (AMTI, 1000 Hz). Trunk horizontal velocity (THV) at touch-down of trailing FL, take-off distance (TOD) and take-off angle (TOA) were calculated from reflective markers (Vicon Nexus, 13 cameras, 200 Hz). Mean values were calculated from ≥2 trials/jump height. Repeated measures ANOVA was used for statistical analysis. THV at touch-down of trailing FL decreased with increasing jump height (P<0.001). TOA became steeper (P<0.001) with no effect on TOD (P=0.34). Mean differences between heights 80 and 120% were -0.37 m/s in HV and 6.30 degrees in TOA. With increasing jump height, the vertical impulse (VI) increased in FLs and HLs (P<0.001). Mean differences in VI between heights 80% and 120% were 0.29 Ns/kg in FLs and 0.24 Ns/kg in HLs. The decelerative horizontal impulse (HI) values decreased in both limb pairs (P<0.001) with mean difference between heights 80% and 120% being -0.097 Ns/kg in FLs and -0.054 Ns/kg in HLs. The accelerative HI decreased in FLs and HLs (P<0.001). The mean differences in accelerative HI between heights 80% and 120% were -0.071 Ns/kg in FLs and -0.046 Ns/kg in HLs. In conclusion, increased jump height is associated with increased braking and decreased horizontal propulsion.

Continuous data analysis can reveal upper-body movement adaptations in horses on an aquatrainer

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Aquatraining is frequently used in horses. Previously, an increase in upper-body vertical range of motion was reported in water and with increasing belt speeds, but data on vertical displacement (DPz) patterns are lacking. Therefore, we evaluated horses' upper-body DPz patterns on a dry- and water treadmill (DT/WT) and compared this with overground movement. Eight Warmblood horses, equipped with inertial measurement units (EquiMoves®) on the head, withers, sacrum, and distal limbs were measured overground and on a DT/WT (water at mid-cannon bone height) at five incremental speeds (3.4-4.2 km/h). Statistical parametric mapping (α=0.5) was used to compare head, withers, and sacrum DPz curves between speeds and between conditions (at 4.2 km/h). Upper-body DPz showed irregular movement patterns at speeds <4.2 km/h. Increasing speed caused a significant increase in amplitudes and delay in timing for the head (at ~50% (DT) and ~75% (WT) of the stride), withers (~20% (DT) and ~70% (DT) of the stride), and sacrum (~5% (DT/WT), ~55% (DT) and ~95% (DT/WT) of the stride). Head DPz curves on the DT/WT were similar, showing lower amplitudes than overground, while sacrum DPz curves on the WT resembled the overground. The withers DPz showed two cycles per stride, with a double peak of similar amplitude per cycle on the WT. Upper-body DPz patterns are affected by speed and water and adaptations are different for head, withers, and pelvis. Irregular movement patterns at speeds <4.2 km/h could indicate insufficient balance. The clinical implications of these results for aquatraining protocols need further investigation.

Kinetics analysis of effects of different angles of box during turning in flyball dogs

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Increasing the angulation of the flyball box to a more vertical plane is perceived as allowing dogs to turn faster, and as such box angles range from 43 to 88°. There are concerns that box angulation may have a role on injury risk, as flyball has one of the highest rates of injury at 39% of participants. Therefore, the purpose of this study was to investigate the effect of different flyball box angles on the passive impact peak (PIP) and peak contact forces (PCF) in a cohort of flyball dogs during contact with the box. 32 dogs (whippets and whippet crosses) regularly competing in flyball have performed three standard flyball runs. Due to ethical concerns, dogs used their usual box angle: 45° (n=7); 50° (n=5); 60° (n=9); 70° (n=6) or 83° (n=5) and were allowed to turn to their usual turn side. The impact of box angle on the PIP (N) and PCF (N/kg) were collected with a pressure mat, recording at 100 Hz, attached to the box, synchronised with 100 Hz videos for identification of limbs contact. Data for outer and inner limbs on the different angles were compared using one-way ANOVA or Kruskal-Wallis. Furthermore, the differences between the inner and outer limbs were tested by paired t-test or Wilcoxon's rank test. There was no significant relationship between the box angle and PIP or PCF (P>0.05). However, overall, greatest PIP and PCF were observed on the outer hindlimb in comparison to the inner hindlimb (P<0.05). No differences were noted between inner and outer forelimbs (P>0.05). In conclusion, the box angle does not seem to play an important role in the magnitude of forces exerted on the limbs. The fact that the outer hindlimb withstands higher forces may explain why it has a higher injury rate than the inner hindlimbs, trend observed in previous surveys. Training techniques should consider dogs being trained to turn to both sides to avoid asymmetrical loads.

Markerless Motion Capture for Evaluation of Biomechanical Strategies in Agility Teeter Performance

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Injury rates of up to 42% are reported for agility canines. Biomechanics and performance variables have been minimally evaluated during completion of agility obstacles, all of which could influence injury risk factors. No studies have evaluated any of these variables with regards to the teeter obstacle. The objective of this study was to quantify time to descent, paw placement, and performance techniques of dogs completing the teeter obstacle. Five dogs of different breeds and sizes were recorded at 120 fps from a laterally-oriented camera and videos were manually tracked in XMALab for 2D coordinates, which were converted to distance measures using the length of the teeter out-lever. Each paw was tracked during contact with the plank and the teeter tip was tracked from the time the dog crossed the pivot-point to ground contact of the plank. Time of plank descent varied by individual (mean = 1.63 sec; range: 1.25-2.37 sec). While variable, some trends in paw placements and footfall patterns were observed: small dogs (Shetland Sheepdog, Papillion) had all four paws in contact with the plank at plank touch-down whereas larger dogs had 1-2 paws in contact with the plank. The number of independent paw contacts during descent showed a similar trend, ranging from 6-15. The variation in these measures suggests that different dogs are using different biomechanical strategies to successfully complete the teeter obstacle. Further work will evaluate the relationship of these teeter performance variables to injury risk in agility dogs.

Trunk roll rotations of dressage horses in canter vs counter canter

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During turning, horses lean inwards to generate a centripetal force, but sport horses are trained to turn with a more vertical posture. The objective was to compare trunk roll angles in dressage horses performing true canter (TC) and counter canter (CC). Sixteen high-level dressage horses were ridden by their trainers in a 20×60 m arena with sand-fibre footing. Trunk roll angle was measured using an inertial measurement unit attached to mid-ventral girth. Data were analysed for 10 strides/horse on 20 and 10 m circles in TC and CC in each direction. Positive roll values indicated the trunk rolled down on the inside of the circle. Descriptive statistics were calculated and compared using a GLM and post hoc tests ($P<0.05$). The trunk rolled inwards under all conditions. For right lead canter, maximal roll was greater for both CC circles (20 m left circle: 4.4±1.2°; 10 m left circle: 4.9±1.7°) than for TC circles (20 m right circle: 2.8±0.9°; 10 m right circle: 2.9±1.2°) ($P<0.001$). Ranges of roll rotation were larger on the right lead in CC (20 m left circle: 7.9±1.6°; 10 m left circle: 8.4±2.0°) than TC (20 m right circle: 5.5±1.3°; 10 m right circle: 5.9±1.5°) ($P<0.001$). Trunk roll did not differ between CC circles on left and right leads. Dressage horses showed less inward lean than expected based on circle size, which is thought to be a dressage training effect. The greater maximal inward roll and range of roll rotation for the right lead CC vs TC warrants further investigation.

Does order and location of movements within Olympic GP Freestyle Dressage influence movement scores?

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Freestyle dressage tests are designed by the rider and combine 16 compulsory movements with music. Individual movements receive a quality score (0-10), which combine to form the technical score. Additionally, the performance receives an artistic score considering the choreography and the order that movements occur. The final score is a combination of technical and artistic scores. When designing freestyle tests, consideration of where and when movements are performed is vital to optimise performance; despite this, performance analysis is limited in dressage. This study explored if the order movements occurred and location performed were associated with superior technical movement scores. Notational analysis identified the order and which quarter of the arena movements were performed in the Tokyo Olympics GP Freestyle test, excluding entrance/finish halts, for the 18 combinations competing. Chi-squared analysis assessed if associations occurred between the most frequent order and arena quarter movements were performed in, and final movement score. Eight movements (53%) scored their highest mark when performed outside of the most frequently observed order and quarter: collected and extended walk, half-pass left and right, one- and two-time changes, and left and right canter pirouette. While the highest marks for seven movements (47%) occurred when performed in the order and quarter they were most frequently observed: extended trot and canter, passage, piaffe and piaffe-passage transitions. Although, no significant associations between the most frequent order and quarter each movement was performed and final movement score, tactically where and when movements are performed could represent marginal gains in elite dressage scoring.

Trunk kinematics of horses when jumping in an International Puissance competition

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This study measured trunk orientation and distance measurements for 24 successful jumping rounds from 12 horse/rider combinations in an FEI International Puissance competition. A triaxial accelerometer with integrated GPS sensor (Alogo™ Move Pro) attached mid-ventrally to the girth was activated throughout the time each horse was in the competition arena. Positive pitch is nose-up, positive yaw is forehand to right of haunches. With a straight approach, horses jumped a triple bar (TB) (1.60-1.70 m high) followed by the Puissance wall (PW:1.80-2.20 m high). Friedman's analysis with post hoc Wilcoxon's signed rank tests identified differences between the PW and TB for the take-off, jump suspension, and landing phases of the jump stride ($P \leq 0.05$). The stride preceding take-off was longer for PW (PW:3.48 m; TB:3.43 m), had higher maximal positive vertical acceleration (mean) (PW:2.92G: TB:2.32G), higher average speed (PW:414 m/min: TB:322 m/min) and smaller trunk yaw (PW: -1.42°: TB: 3.48°) (all P=0.0004). During the jump suspension, when horses jumped the PW they raised the body higher (PW: 2.3 m: TB: 1.9 m, P=0.0004); had a larger average trunk pitch while ascending (PW 42.4°: TB: 36.3°, P=0.001) and negative vs positive trunk yaw (PW: -0.95°; TB: 3.2°, P=0.0004). When landing, the stride following the jump was shorter for PW (PW:1.82 m: TB:2.06 m, P=0.018), higher negative maximal vertical acceleration (PW:-3.26G: TB:-1.97G, P=0.008) and negative vs positive trunk yaw (PW: -1.41°: TP: 3.14°, P=0.0004). This equipment identified several features that distinguished jumping performance over two fence types, with accelerations being particularly interesting.

The effect of fatigue on locomotion in young Friesian stallions during a 10-week training programme

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In horses appropriate training is essential to improve fitness and welfare. Young Friesian stallions must complete a 10-week stallion-training-programme (STP) for acceptance as breeding stallion. This STP demonstrated earlier to induce overtraining. The present study evaluated the effects of this STP on stallions' locomotion variables, hypothesising that fatigue decreases stride duration (StrideD) and range of motion (ROM) of limbs and withers. Friesian stallions of 3.2±0.4 years old performed ridden indoor standardized-exercise-tests (SETs) in week-1 (SET-I; n=15), week-6 (SET-II; n=11) and week-10 (SET-III; n=4) of the STP, measuring plasma lactate concentration (LA, mmol/l). Before and after SETs, stallions' locomotion was measured (EquiMoves® (200 Hz)) in-hand in trot on a straight line. StrideD and stance duration (StanceD (sec)), limb protraction ($P_{forelimbs}$, $P_{hindlimbs}$ (°)), and ROM of the withers ($ROM_{withers}$ (mm)) were calculated. Linear mixed models were used to analyse gait variables related to SET and peak LA>4 or LA<4 during SETs. Data is presented as estimate and 95% confidence interval (95%CI). Overall, StanceD, StrideD and $P_{hindlimbs}$ in SET-II and SET-III decreased compared to SET-I. Horses with peak LA>4, had lower StrideD (-0.02; 95%CI -0.04, -0.004), $P_{forelimbs}$ (-2.4; 95%CI -3.7, -1.1) and $ROM_{withers}$ (-8.0; 95%CI -12.7, -3.4) compared to horses with peak LA<4. In all horses, $ROM_{withers}$ (-5.6; 95%CI -7.4, -3.8) decreased post-SET. The decreased StanceD, StrideD, $P_{forelimbs}$ and $P_{hindlimbs}$ and $ROM_{withers}$ over time and after SETs during the 10-week STP suggest an effect of fatigue in the locomotion pattern, indicating that the effect of overtraining was also visible in locomotion patterns.

Diagonal dissociation in collected and extended trot in Prix St George and Grand Prix dressage

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In dressage positive diagonal dissociation (DD) is a desirable gait feature but is poorly understood within competition. The aim was to identify positive (advanced HL ground contact); neutral (HL-FL landing simultaneously), or negative (advanced FL ground contact) DD when in collected (CT) and extended trot (ET) during a Prix St. George (PSG) and Grand Prix (GP) dressage test. Forty-nine horses were observed (GP n=18, PSG n=31). Two cameras (240 Hz) recorded CT between the X-C markers and ET between the H-F markers during the PSG and GP. The presence of DD and direction (positive/negative) were recorded. Hoof impact and lift-off for each diagonal pair (RF-LH/LF-RH), for three repeated strides, were visually determined. Wilcoxons compared CT and ET and Mann Whitney U compared PSG/GP. Spearman's tested for relationships between DD and judges score ($P \leq 0.05$). Positive DD occurred in both classes(PSG=357/372 strides, GP=204/216 strides). Neutral ground contact and negative DD were found in the GP during ET (Neutral:4/216; Negative:8/216).Negative DD was found in the PSG (CT=6, ET=9). Longer DD in CT was seen during the GP, (LF-RH: CT=0.05±0.03 s, ET=0.04±0.03 s, P=0.007; RF-LH: CT=0.05±0.02 s, ET=0.03±0.02 s, P<0.001). RF-LH pair had a longer DD (CT=0.05±0.02 s, ET=0.03±0.02 s, P<0.001) in the PSG. At GP, DD at ET was greater for LF-RH pair compared to PSG (GP=0.04±0.03 s, PSG=0.04±0.02 s, P=0.007). No correlations with DD and judges score were seen (P>0.05). In advanced competitive dressage horses, positive DD was highly prevalent; but there were no associations with DD and judges scores suggesting its high prevalence reduces the impact on performance outcomes.

Back flexion-extension in free jumping warmbloods

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The purpose of the study was to define baseline values for back movement with high spatial resolution in the saddle region of free jumping horses. 8 horses (4-6 years) were equipped with 49 spherical reflective markers covering the back in what would be a normal saddle position plus a section of the area (appr 10 cm) in front of and behind this position. Markers were arranged in columns and rows spaced 10 cm apart with T6 spinous process as anatomical reference. Each horse were jumped successively up to their training level (120-140 cm) on an oxer and an upright fence while recorded at 120 frames per second with a 30 camera Qualisys locomotion analysis system. Flexion-extension angles were calculated over three sequential markers along the back (rows of markers) in (para-)sagittal planes. For this study, flexion-extension of the back was quantified using the markers in the first rows on the left and right side of the horse (positioned approx.10 cm from and parallel to the midline) in the form of 6 angles representing flexion-extension at approximately T8, T10, T12, T14, T16 and T18. There were no statistical significant difference between left and right side angles. Lateral bending and axial rotation were also calculated. These data supply baseline values with a resolution that can be important when developing saddle constructions that would allow movement freedom for horses during jumping.

Asymmetrical limb patterns in show jumpers

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Asymmetrical footfall preferences in horses when jumping could influence limb loading patterns but have yet to be characterised. Footfall patterns were characterised in horses loose jumping. It was hypothesised horses would show asymmetrical lead limb preferences. Eight show jumpers (4 mares and 4 geldings) fitted with anatomical markers, loose jumped a grid exercise of three fences. Two cross poles framed a vertical fence (0.8-1 m), two strides separating each fence. The vertical jump was video recorded (1,920×1,080, 60 Hz) and kinematic data extracted using Dartfish software®. At take-off and landing, leading fore and hindlimb were identified. The distance between trailing and leading limbs was measured at take-off. Laterality indexes ((R-L)/(R+L)) characterised limb patterns. The data met assumptions for normality and variance. Pearson's correlations investigated relationships between forelimbs and hindlimbs patterns. Two-sided t tests assessed population bias and sex differences. 50% of horses displayed significant laterality indexes (Z-score>1.96) indicating a strong lead leg bias. No correlations were found between fore and hindlimb preferences, nor between take-off and landing patterns ($P>0.10$). The mean (± SD) distance between leading and trailing forelimb at take-off was 0.87±0.24) m. Hindlimbs were asymmetrical in 75% of take-offs, with a mean distance of 0.25±0.23 m between leading and trailing hindlimb. At take-off, mares favoured a left hindlimb lead significantly more than geldings (mean ± SD 64.5±11% of take-offs vs 38.5±16%; $P<0.05$). Limb patterns suggest high inter-individual variability in show jumper technique and biomechanics that may reflect individual preferences.

Effect of a training session on movement asymmetries in riding horses-pilot study

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The presence of movement asymmetries (MA) in horses in training has been described. However, the training influence on MA has not been evaluated. Objectives were to evaluate MA before and after the training with a hypothesis of change in the degree of asymmetry. Vertical head, withers and pelvic asymmetries were measured in 14 horses (mean age of 11.2 years) in training perceived as non-lame by the owner. Inertial sensors were mounted at the poll, withers and pelvis to measure gait kinematics during ≥25 strides of straight trot in-hand immediately before and after training (standardized for all horses, flatwork of 45-60 min). Range of motion (ROM) and absolute differences between vertical displacements (VD) minima (MinD) and upward amplitudes (UpD) were tested for change due to training in general and for an increase above normal thresholds. The overall mean difference in ROM after training showed a decrease of -4.9 mm (means from -11.9 to -1.3) with significant changes only for poll parameters (P MinD 0.03; UpD 0.02). The overall mean difference in absolute VD asymmetry parameters after training was 8.6 mm (means from 4.6 to 14.6) and considering normal thresholds a significant increase was observed in the upward amplitudes (P poll 0.02; withers 0.05; pelvis 0.05). Movement asymmetries in our group of horses differed after training. The asymmetry was less pronounced on poll parameters. The results could be caused by daily variations of MA but also by a possible decrease in pain or mechanical abnormalities and differences in propulsion due to training.

Does individual movement score within Olympic GP Freestyle Dressage influence overall test score?

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Freestyle dressage tests allow riders to showcase their creativity by designing tests which optimise their horse's performance strengths to music. Scoring considers movement quality and artistic expression, which encompasses test choreography and fit of movements to the musical score. Despite the potential of performance analysis to inform test design, application is currently limited in Dressage. This study aimed to identify the influence of individual movement scores in Olympic Grand Prix Freestyle (GPF) Dressage on judges' overall test score. Videos of the GPF tests performed by the 18 combinations participating in the Tokyo Olympics were reviewed by a consistent observer. Spearman's correlations assessed if relationships existed between the final score for each movement and the overall test score for judges at K, C, E, H, M, B and F. Final movement score was positively correlated with overall test score for 12 of the required technical movements: half-pass right (K,E,H: P<0.009; r: 0.60-0.66) and left (E,H,C,M,B: P<0.04; r: 0.57-0.80); extended canter (F: P=0.002; r=0.69); one-time changes (K,E,H,B,F: P<0.03; r: 0.51-0.77), two time changes (E,H,B,F: P<0.008; r: 0.61-0.75); canter pirouette right (K,E,H,M,B: P<0.005; r: 0.68-0.83) and left (K,E,H,M,B,F: P<0.03; r: 0.58-0.78); passage (K,E,H,C,M: P<0.03; r: 0.51-0.77); piaffe (K,E,H,C,M,B,F: P<0.009; r: 0.54-0.85) and piaffe-passage transitions (K,E,H,C,M.B,F: P<0.001; r: 0.64-0.86). In contrast, no correlations were found between collected walk, extended walk, and extended trot and overall test score. These preliminary results suggest the influence of movement vary by judge location and scores for walk and trot movements have limited influence on judges' final test score.

Single osteopathic treatment of the sacroiliac joint has little effect on protraction-retraction

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Pain in sacroiliac joints (SIJ) is thought to reduce protraction-retraction (P-R). We studied the effects of a single osteopathic treatment of a blocked SIJ on P-R in 29 sport horses with osteopathic dysfunction of one SIJ and no obvious lameness (≤1/5 AAEP). An expert osteopath treated 21 horses (T), 8 untreated were controls (C). Measurements were done at trot before and on days 1, 3 and 15 post-treatment placing inertial measurement units (Equimoves system®) lateral to the 4 cannon bones, GPS tracked speed. Max P-R angles of hindlimbs were calculated and differences tested with linear mixed-models and Tuckey's. Max P in right hindlimb (RH) (mean degrees, [confidence intervals]) was: group T day 1: 31.29 [30.03, 32.55], day 15: 30.98 [29.80, 32.17] and C day 1: 32.09 [29.99, 34.20], day 15: 29.54 [27.60, 31.48]. Max R in RH was: T day 1:-22.33 [-24.14, -20.52], day 15: -25.41 [-28.15, -22.67] and C day 1: -24.97 [CI 27.98, -21.96], day 15: -25.41 [-28.15,-22.66] (P<0.001). Max P in left hindlimb (LH) was: T day 1: 31.25 [29.99-32.54], day 15: 30.94 [29.33-32.58] and C day 1: 30.41 [28.27-32.56] day 15: 29.99 [27.33-32.64]. Max R in LH was: T day 1: -22.06 [-23.95, -20.21], day 15: -21.38 [-23.05, -19.68] and C day 1: -25.88 [-28.97, -22.73], day 15:-25.01 [-27.77, -22.24] (P=0.072). Results showed small unilateral but significant changes in protraction and retraction. Increased retraction may indicate improved impulsion. Studies are needed at other gaits and with repeated treatment(s) as usually done in osteopathy.

Effect of jump height on kinetics at landing in agility dogs

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Agility dogs sustain sport-related injuries. We aimed to evaluate the effects of jump height on the landing kinetics. Fifteen Border Collies (wither height 44-56 cm) performed bar jumps in a straight-line at 80%, 100% and 120% of the dogs' height. Impulses of fore- and hindlimb (FL/HL) pairs were calculated from forces measured by two force plates (AMTI, 1000 Hz). Trunk horizontal velocity (THV) at touch-down of trailing FL, landing distance (LD) and landing angle (LA) were calculated from reflective markers (Vicon Nexus, 13 cameras, 200 Hz). Mean values were calculated from ≥2 trials/jump height. Repeated measures ANOVA was used for statistical analysis. THV at touch-down of trailing FL decreased with increasing jump height (P<0.001), LA became steeper (P<0.001), and LD increased (P<0.001). Mean differences between heights 80% and 120% were -0.86 m/s in HV, 7.20 degrees in LA, and 0.58 m in LD. As jump height increased, the vertical impulse (VI) increased in both FLs and hindlimbs (HLs) (P<0.001). Mean differences in VI between heights 80% and 120% were 0.42 Ns/kg in FLs and 0.17 Ns/kg in HLs. The decelerative horizontal impulse (HI) was not affected by jump height in either limb pair (P>0.26). The accelerative HI increased with jump height in FLs (P<0.001) and HLs (P=0.002) with mean difference between heights 80% and 120% being 0.092 Ns/kg in FLs and 0.067 Ns/kg in HLs. Increased horizontal propulsion and vertical impulses of both limb pairs at higher jump heights may have an impact on sport-related injuries.

Validation of the Alogo Move system for assessment of jumping performance

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Quantitative information on the manner in which a horse clears a jump has great potential to support the rider in improving the horse's jumping performance. This study aimed to validate a single sensor IMU system fitted with a GPS receiver chip (Move Pro, Alogo Analysis SA) against an optical motion capture system (OMC). Accuracy and precision of three jumping characteristics were compared: maximum jumping height (JH_{max}), jumping length (JL), maximum take-off angle (TOA_{max}). Eleven horse-rider pairs repeated several jumps (between 6 and 10) over upright fences and oxers of different heights (80 to 140 cm) in a 60×20 m tent arena on a fibre sand surface. Twenty-four cameras (Oqus 7+, QualisysAB) were suspended 3 m above floor covering a calibrated area of 10×20 m. The Alogo sensor was placed in a pocket on the saddle girth over the sternum. Five reflective markers placed on and around the Alogo sensor were used to define a rigid body for kinematic analysis. Both systems sampled at 100 Hz. Alogo sensor data were collected and processed using the Alogo proprietary software; stride-matched OMC data were collected using Qualisys Track Manager and post-processed in Python. Residual analysis and Bland Altman plots were done in R-Studio. Correlation rho was 0.96 for JH_{max}, 0.74 for JL and 0.84 for TOA_{max}. Average JH_{max} was overestimated by 8±4 cm), JL was underestimated by 47±55 cm) and TOA_{max} was underestimated by 0.86±2.96°) by the Alogo system. Accuracy and precision were deemed sufficient under conditions (tent) where GPS signal strength might have been suboptimal.

Session 6 – Clinical Applications, Lameness

Chiropractic treatment of lameness and concurrent axial skeleton pain and dysfunction in horses

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Chiropractic is common treatment modality used in equine practice to manage back pain and stiffness; however, there is limited evidence for managing lameness. The objective of this controlled clinical trial was to evaluate global effects of chiropractic treatment on chronic lameness and concurrent axial skeleton dysfunction. 20 collegiate polo horses with multilimb lameness and 18 privately-owned Quarter Horses (QH) with primary hind limb lameness were randomized into treatment (days 0, 7, 14 and 21) and control (no intervention) groups. Outcome parameters were recorded on days 0, 14, and 28, which included subjective and objective lameness examination, mechanical nociceptive thresholds (MNT), and manual assessment of spinal pain, stiffness, and muscle hypertonicity. Results were reported as percent change from baseline, where negative values represent improvements (except MNT, where a positive value represented an increased pain threshold). Data was analysed by a mixed model fit separately for each response variable ($P<0.05$). Thoracolumbar pain (-86%; $P=0.03$) improved in the treated polo horses. Axial skeleton stiffness (-25%; $P=0.03$) and lumbosacral MNTs (23% kg/cm^2/sec; $P<0.01$) improved in treated QH. A positive hindlimb (-20%; $P=0.08$) and global lameness (-14%; $P=0.03$) effect in treated QH was observed. Inconsistent therapeutic effects were assessed in objective global lameness scores (polo 25%; $P=0.23$ and QH 12.5%; $P=0.37$) and subjective epaxial muscle hypertonicity (polo -10.7%; $P=0.69$ and QH 6.7%; $P=0.72$). Results suggest that chiropractic treatment had some, but inconsistent positive effects on lameness, back pain, and stiffness. Limitations include the presence of chronic, multilimb lameness and lack of pathoanatomical diagnoses.

Assessing static postural types in sport horses

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Postural assessment, within equine physiotherapeutic assessment, provides information about clinical condition, however, evidence-based methods to identify horses' postural type are scarce. Horses' postural type (sway-backed, straight-backed, or S-backed) is associated with features such as spinal alignment, muscle balance and movement (dys)functions. This study aimed to develop an Equine Postural Assessment Tool (EPAT) and to evaluate its inter-rater agreement. An EPAT template, guidance document and video were developed to support evaluation of horses' static postural type based on 25 possible observations in six body zones. The EPAT was used to evaluate 21 sport horses' postural type based on side-view standing photographs. The inter-rater agreement for EPAT scores was evaluated between seven ACPAT Veterinary Physiotherapists (P1-P7) using Kappa-agreement coefficients. P2 and P3 received verbal training from P1 about how to score horses' postural type using the EPAT, after which the EPAT was updated with the complementary guidelines. P4-P7 received these guidelines only to score horses' postural type using the EPAT. Excellent agreement (average κ=0.893, P<0.001) were obtained between P1, P2, P3 scoring horses' postural types using the EPAT, whilst fair-to-good levels of agreement were found between all evaluators (P1-P7) (average κ=0.519, P<0.05). The EPAT was found reliable to evaluate horses' postural type from side-view standing photographs. The tool is a simple and promising tool to assess horses' static postural type, which could support practitioners in their clinical reasoning and decision making. Further research is warranted to establish the EPAT intra-rater reliability, reliability in live horses, and its association with horses' movement (dys)functions.

Longitudinal study of vertical head and pelvic movement asymmetry in dressage horses

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Competing horses are exposed to a high workload throughout a competition season which may lead to musculoskeletal injuries and lameness. The study aim was to investigate movement asymmetries in dressage horses during one competition season. Movement asymmetries in a convenience sample of 19 Warmblood sporthorses and one pony competing between Novice and Grand Prix level were assessed, measuring vertical head and pelvic movement symmetries using inertial sensors (Equinosis Q). Measurements were performed at the trot in hand on a straight line on a hard surface, in the beginning, halfway, and at the end of one winter season. Information on health status and perceived performance was obtained from the riders. Twenty horses (range 4-14 years) completed the study. During the competition season, 24/60 forelimb and 34/60 hindlimb measurements were within published reference ranges. Only 5/20 and 14/20 horses presented measurements consistently within reference ranges for fore- and hindlimbs, respectively. Twelve of 36 forelimb measurements outside the reference range were at least twice the reference range, whereas hindlimb measurements did not reach this level of asymmetry. In 16/20 horses, rider's perception was inconsistent with measured asymmetry. Previous studies showed a high prevalence of movement asymmetries above published reference ranges in polo horses and standardbreds. It is noteworthy that these asymmetries occur in dressage horses – a sport in which symmetry is crucial to the proper execution of movements. Main limitations are limited clinical information, lack of a repeatability assessment and small sample size. More research is needed to determine the association with performance.

Longitudinal study of vertical head and pelvic movement asymmetry in event horses

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Event horses are exposed to a high workload throughout a competition season. In this prospective, longitudinal evaluation of movement asymmetries in a convenience sample of 15 Warmbloods competing at international level eventing, head and pelvic vertical movement asymmetries were measured using inertial sensors (Equinosis Q) over one year. Measurements were performed at the start, halfway, at the end of the competition season, and at the start and end of the winter break (preparation period for next season). Information on health status and perceived performance was obtained from the riders. Ten horses (range 7-14 years) successfully completed the study. During the competition season, 29/70 forelimb and 22/70 hindlimb measurements were within published reference ranges. Seventeen forelimb and 24 hindlimb measurements were at least twice the reference range. At the start of the winter break, 7/10 forelimb and 3/10 hindlimb measurements were within published reference ranges. At the end of the winter break, 3/10 forelimb and 3/10 hindlimb measurements were within published reference ranges. In 5/10 horses, rider's perception was inconsistent with measured asymmetry. Main limitations of the study are limited clinical information, lack of a repeatability assessment and the small sample size. In conclusion, a large proportion of event horses – a sport in which a vet check takes place prior to competition and in which dressage is an elementary part of the competition – presented movement asymmetries which were not consistently perceived by the rider, and which decreased during the rest period. More research is needed to determine the association with performance.

Walk characteristics of horses clinically lame in trot

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Lameness in horses has mostly been studied in trot, since the symmetric gait with bipedal support phases makes the biomechanical interpretation of asymmetric movement easier. However, on occasions, trotting a horse is contraindicated. Therefore, it would be beneficial to better understand the changes in movement associated with lameness in walk. Walk kinematics were recorded during lameness exams using optical motion capture. Mean difference for head(H)/withers(W)/pelvis(P) between the local vertical displacement minima (HDmin/WDmin/PDmin) and maxima (HDmax/WDmax/PDmax) and the difference in hike (HRUD=HDmax+HDmin, PRUD=PDmax+PDmin) were computed per trial. The horses were included if they fulfilled a certain lameness criterion in trot (HDmin or HDmax>15 mm or HRUD>20 mm for forelimb lameness or PDmin or PDmax>7 mm or PRUD>10 mm for hindlimb lameness) and the measured asymmetry improved by at least 70% after diagnostic analgesia. In total 18 forelimb and 22 hindlimb lame horses were included. The walk kinematics before and after analgesia were compared using paired t-tests. In forelimb lame horses the WDmax decreased on average 2.7 mm (CI [0.78 4.6], α=0.05) after diagnostic analgesia, and similarly the hindlimb lame group showed a decrease in PDmax of 1.8 mm (CI [0.35 3.2], α=0.05) in walk. There were no significant differences in vertical range of motion for the measured points or in stride frequency or duration in either group. In conclusion, only small differences were observed in walk kinematics before and after diagnostic analgesia. This is not unexpected, since the inclusion criterion corresponds to a quite mild lameness in trot, and the dynamic forces are considerably lower in walk.

Observing veterinary students during subjective lameness assessment using eye-tracking technology

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Gait analysis is essential in equine veterinary medicine. However, teaching students to evaluate lameness in horses is challenging. In this study, our goal was to observe the eye movement behaviour of students during a live lameness examination. Ten first year master and ten third year master students were fitted with Tobii Pro 2 glasses to track their eye movements while assessing three horses (walking, trotting on a straight line, lunging on a hard surface) and were asked about the lameness assessment. A Mann-Whitney U test compared the duration of fixation (DF) on areas of interest (AOI) and the number of fixations (NF) on each AOI. Overall, the percentage of DF was higher on the frontlimbs ($P<0.04$) compared to the head on the straight line. On the lunge, there was a significant higher percentage of DF between frontlimbs and withers/head/sacrum ($P<0.02$) but not the hindlimbs. NF was significantly higher for the hind limbs compared to the sacrum, head and withers ($P<0.01$). There was no significant difference in DF or NF between AOIs on the straight line and the circle when comparing the two groups. The most named AOI on the straight line by the inexperienced group was the sacrum, with 93% and the head, with 96% for the experienced group. The most named AOI on the straight line was the sacrum (93%) for the inexperienced group or the head (96%) for the experienced group. This information will help tailor teaching strategies for students to improve subjective lameness assessment.

Comparison between IMU-based, markerless technology and subjective evaluation in detecting lameness

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Objective lameness evaluation systems may aid equine clinicians as lameness is not always reliably detected. In the current study, identification of lame limbs was compared between a novel markerless lameness detection system (SleipAI); a sensor-based system (Equinosis Q with Lameness Locator®, LL); and subjective evaluation (SE). Forty-nine presumably sound horses were trotted twice (trial 1+2) while data was collected by the LL and the SleipAI recorded on two different Iphones. SE lameness was assigned based on both trials, and scored using the Ross 0-5 scale in order to assess lameness during straight line trot only. Asymmetry data was extracted, and limbs were categorized as either sound or lame using reported thresholds for each system. Intra-class coefficient (ICC; objective data) and inter-rater reliability (Light's Kappa) was calculated per limb; each horse was classified as sound, left or right front lame and/or left or right hind lame. The test-retest repeatability was excellent for objective methods (ICC 0.85-0.95). There was substantial inter-rater agreement between the objective methods (κ=0.70) for forelimb lameness, whereas agreement was moderate (κ=0.52,) when including SE. For hind limbs, there was moderate agreement (k=0.49) between the objective methods and fair (κ=0.36) when including SE. All objective methods demonstrated excellent test-retest agreement. There was substantial agreement between the objective methods in determining front limb lameness, and moderate agreement for hind limbs. In conclusion, our data support the usefulness of a markerless lameness detection system in a clinical setting.

Facial activities in trotted horses during progression and regression of induced lameness

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Facial displays of pain are present in resting horses with orthopaedic pain, and if present during motion they may aid in assessing movement-evoked orthopaedic pain in horses. This study aimed to identify facial activities associated with pain in moving horses with induced orthopaedic pain. Video sequences (n=60) of eight horses trotted in a straight line before, during and after lipopolysaccharide-induced synovitis in one tarsocrural joint, were annotated with the equine Facial Action Coding System (EquiFACS). A motion capture system was used to measure movement asymmetry, mean 6.1 standard deviation 1.7 times per horse, within 52 hours after induction. The study protocol was approved by the Swedish Ethics Committee (5.8.18-09822/2018). Each video was classified as increasing, maximum or decreasing pain intensity based on changes in total asymmetry score TAS = |PDmin| + |HDmin/2| (mean increase 27 mm). Regularized logistic regression modelling identified facial action units (AUs) and descriptors (ADs) associated with different pain intensities and soundness and an inter-individual difference in facial expressiveness. With data-driven selection of co-occurring AUs/ADs during observation windows of 2 seconds, a dynamic facial repertoire consisting of blink (AU145), eye white increase (AD1), upper lip raiser (AU10), lower lip depressor (AU16) and lips part (AU25) was identified during lameness, further confirming that nuances of the prototypical and more stoic pain face exist. In conclusion, horses show facial displays of pain when they are lame during straight line trot, but further research is required to identify facial displays of pain in naturally lame horses during locomotion.

The influence of hard and soft surface on equine upper-body movement

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Observing horses in motion on hard and soft surfaces is part of clinical lameness examinations. In this study, we investigated the influence of surface type (i.e. hard vs soft) on upper-body movement in owner-sound horses at trot. Seventeen horses (9.2±3.1 years) were equipped with seven Inertial Measurement Units (IMUs) at the poll, withers, pelvis, and cannon bones. Data was collected from each horse trotting on a hard and soft surface on a straight line and on the left and right circle. Linear mixed models (random effect='horse', fixed effect='surface', confounding variable='stride frequency', α=0.05) were used for statistical analysis, presenting results as percentage change. On the straight line, the head, withers and pelvis had larger vertical range of motion (ROMz) on the soft surface (P<0.01, 5.6, 10.0 and 12.8%, respectively) than on the hard, while upper-body asymmetry parameters (MinDiff and MaxDiff) remained unchanged. On the circle, ROMz of the head, withers and pelvis were also larger on the soft surface (P<0.01, 7.6, 16.7 and 13.8%, respectively). The MinDiff and MaxDiff of the head were smaller on the soft surface on the circle (P<0.01, -18.2% and -11.5%, respectively), but larger for the withers (P<0.01, 27.4 and 12.7%, respectively). Pelvis MinDiff was larger on the soft surface on the circle (19.8%, P<0.01). Horses deemed sound by their owners, show differences in upper-body movement on the hard and soft surface. Thus, these findings suggest that differences in gait kinematics across various surfaces, cannot invariably be attributed pain or lameness, but also adaptions to surface properties.

Effect of transcutaneous electrical nerve stimulation (TENS) on gait parameters in dogs

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Transcutaneous electrical nerve stimulation (TENS) is used in dogs as a pain relieving treatment. This randomized, controlled cross-over study investigated the effect of TENS on stance time, swing time, stride time and stride length. The hypothesis was that gait parameters would differ between dogs receiving TENS compared to placebo. Twenty-two dogs with low to moderate lameness and chronic musculoskeletal pain were included. Thirteen dogs had confirmed diagnosis of osteoarthritis by diagnostic imaging and four dogs were treated simultaneously with NSAIDs during the study. The dogs were randomized to either TENS treatment (80 Hz pulse, duration=100 μs, individually set intensity) of the lame leg once daily for 45 minutes -or placebo, with a washout period of 7-10 days between interventions. Gait parameters were registered in trot with a pressure sensitive mat (Walkway High Resolution HRV4; Tekscan Inc.), before and after the first treatment session and after 8-10-days of treatment. Gait parameters from two trials per run were analysed with a linear mixed effects model in R, $P<0.05$. In the linear mixed effects model dog was set as random effect and age, sex, weight, simultaneous NSAID treatment and velocity was set as fixed effects. No significant differences were seen between treatment and placebo in stride time, swing time, stance time or stride length. Thus our hypothesis is rejected. Further studies are needed to confirm the results and its clinical implication. This research was funded by Agria Pet Insurance and the Swedish Kennel Club.

Are certain positive diagnostic blocks more common in impact or push-off lameness patterns?

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Objective lameness measurement typically output metrics indicating asymmetrical vertical motion of the head/pelvis during the weight-bearing phase (HDmin/PDmin) or the propulsive phase (HDmax/PDmax) of contralateral steps, referred to as impact and push-off lameness respectively. It is unknown if these lameness patterns are typical for pain originating from certain anatomical regions. Therefore, we studied the proportions of different positive diagnostic analgesic blocks for impact, push-off and mixed (both impact and push-off) lameness patterns in a population of equine orthopaedic patients at four European equine hospitals. In total 1,208 horses underwent routine lameness assessment using optical motion capture, and were measured before and after administration of a local analgesic block to one limb. From these, 317 were included based on two criteria: Baseline asymmetry above a certain magnitude for at least one variable: HDmin/HDmax >|15| mm, PDmin/PDmax >|7|mm, and >70% decrease of the initial asymmetry in response to the block. Three lameness pattern groups were created for fore-/hindlimb lameness respectively, depending on the asymmetry variable(s) that met inclusion: impact only (HDmin, n=72) / (PDmin, n=31), push-off only (HDmax, n=42) / (PDmax, n=55) and mixed (HDmin and HDmax, n=29) / (PDmin and PDmax, n=29). Proportions of regional pain origins (blocks) with >10 observations were compared between groups (Fisher's exact test) with no significant differences found. Proportions were borderline significant (P=0.09) for positive coffin joint blocks, with the impact forelimb lameness group having 17% of horses blocked to the coffin joint, compared to 6% in the push-off and 3% in the mixed groups.

Impact of lunge direction on lameness severity in horses with naturally occurring forelimb lameness

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Lungeing is commonly used during lameness and pre-purchase evaluations since it may increase the degree of lameness compared to straight line trot. In addition, orthopaedic textbooks describe increased lameness for certain orthopaedic disorders when the lame limb is inside or outside on the circle. This study investigated differences in the severity of forelimb lameness between lungeing directions. Upper-body movement symmetry was measured during lameness examinations at three equine clinics using optical motion capture during lungeing (size not strictly controlled) and straight line trot at the horses' preferred speed. The mean difference for the head between the local vertical displacement minima (HDmin) and maxima (HDmax) was determined for each measurement. Horses (n=80) with HDmin or HDmax >|15| mm (motivated by clinical experience) and >70% reduction for one or more variables on the straight line after local diagnostic analgesia were included. Wilcoxon signed rank tests assessed differences between directions. Prior to blocking, both HDmin (P<0.01) and HDmax (P<0.05) asymmetries were more pronounced with the lame limb to the inside during lungeing. Some exceptions to this were found. Horses (n=8) with lameness responding to a low 4-point block, where HDmax had similar magnitude in both directions, and horses (n=2) with blocks to the fetlock joint, where mean HDmax was greater with the lame limb to the outside. In conclusion, forelimb lameness became more prominent with the lame limb to the inside of the circle. Specific diagnoses and their pattern on the lunge need to be explored further in order to improve orthopaedic diagnostics.

Compensatory asymmetry in horses with naturally occurring lameness on the lunge – a multicenter study

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Compensatory movement patterns during lungeing have been described in horses with induced lameness. However, there is scarce evidence in naturally occurring lameness cases. Therefore, we investigated compensatory asymmetries on the lunge in such a population. Movement asymmetry was measured in trot using optical motion capture. Study included 91 horses presented for lameness investigation at three equine clinics. Mean difference for head/withers/pelvis between local vertical displacement minima (HDmin/WDmin/PDmin) and maxima (HDmax/WDmax/PDmax) were calculated for each trial. Four lameness groups were created: HDmin, HDmax, PDmin and PDmax based on initial straight line asymmetry >|15|mm for HDmin/HDmax and >|7|mm for PDmin/PDmax groups, and >70% reduction in straight-line of this baseline asymmetry following diagnostic analgesia. Associations between the change in the group parameter due to diagnostic analgesia and the corresponding change in the other measured asymmetry parameters during lungeing (~10 m circle, hard/soft surface) were evaluated using linear models (P<0.05). In the HDmin/HDmax groups (n=55) for each 1 mm decrease in lameness there were significant correlated decreases in WDmin (0.13-0.22 mm), PDmax (-0.16 to -0.10 mm) and WDmax (0.06-0.14 mm, except HDmin group with lame limb to the inside). In the PDmin/PDmax groups (n=36) WDmin (-0.62 to -0.27 mm), WDmax (-0.64 to -0.18 mm, except PDmin group, lame as inside) and HDmin (0.77 mm, only PDmax group as inside) decreased. Forelimb lame horses show compensatory withers asymmetry on a circle indicating the lame forelimb along with diagonal hindlimb lack of push off. Hindlimb lame horses show withers asymmetry indicating the diagonal forelimb. A compensatory head-nod was seen in horses with hindlimb push-off lameness.

Influence of lunge direction on lameness severity in hindlimb lame horses

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Lungeing is commonly performed during lameness exams. Orthopaedic textbooks suggest that lameness caused by certain pathologies is exacerbated with the lame limb positioned either to the inside or outside of the circle. The aim was to investigate if hindlimb lameness severity is affected by the position of the lame limb during lungeing. Movement symmetry was measured using optical motion capture during lameness examinations (on hard or soft surface) while lungeing (10-15 m) and in straight line trot. The mean difference for pelvis between the local vertical displacement minima (PDmin) and maxima (PDmax) were calculated for each measurement. Horses (n=58) with PDmin/PDmax >|7|mm and >70% reduction in asymmetry on the straight line after local anaesthesia were included. A paired-Wilcoxon signed rank-test tested differences between directions. Horses showed an increased PDmin with the affected limb to the inside of the circle when compared to the other direction (*P*<0.0001). For PDmax, median value for the affected limb were instead higher as outer limb on the circle but non-significant (*P*=0.065) and resembled the straight line in magnitude. In four out of five horses with PDmax-lameness blocked in the stifle, the lameness was exacerbated with the lame limb to the outside of the circle. In conclusion, we show that horses with an impact (PDmin) lameness are more lame with the affected limb to the inside of the circle. No difference between inner or outer limb could be found for push-off lameness (PDmax). Specific diagnoses and their relation to different movement patterns during lungeing should be further explored.

Speed of sound variation as an indicator of tendon functional recovery after an injury in ten horses

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Objective methods to assess superficial digital flexor tendon (SDFT) functional recovery after an injury are lacking. Our goal was to use speed of sound (SOS) measurement to follow up a group of racehorses during their rehabilitation after a SDFT injury, and compare SOS data with the horses' subsequent performances. Ten steeplechasers (4.5(0.8) years) suffering from a recent fore SDFT injury were followed. SOS measurement (Tensonics, axial transmission, 1 MHz) was performed every 5 weeks in average during rehabilitation. After clipping then depilating the palmar metacarpal area, the probe (1 emitter, 2 receivers 1 cm apart) was placed in an adapted gaiter facing the maximal severity zone as defined ultrasonographically. SOS between the 2 receivers was measured on 20 strides of walk (measurement session). Ten SOS measurement sessions were performed in average on each horse during rehabilitation. Reinjury appeared at training (before racing) in 4 cases; another horse reinjured after 3 races. For these 5 horses rehabilitation was considered 'non successful' (N_S). For the other 5 horses, who did 3 to 17 (7.8(5.5)) races without reinjury, rehabilitation was considered 'successful' (S). Statistical analysis was performed using Student t-test. Although the final SOS (maximal value during stance) tended to be higher in the S-group (2,067 (77) vs 1,987 (100) m/s), this difference was not significant. Conversely, the average SOS variation rate during the last 100 days of rehabilitation was significantly larger in the S-group (*P*=0.006; +0.09 (0.24) vs -0.33 (0.18) m/s/day). SOS variation rate is a potential relevant indicator to assess tendon functional recovery after an injury.

Upper body range of motion in horses is influenced by lameness severity and trotting speed

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It is unclear how lameness severity and speed affect the vertical range of motion (ROMz) of upper-body landmarks used for lameness evaluation in horses. This study aimed to assess how lameness severity, based on movement asymmetry magnitudes, affected the ROMz. Speed was evaluated as a cofounding factor. ROMz of head (H_ROMz), withers (W_ROMz) and pelvis (P_ROMz) before and after diagnostic analgesia was quantified during straight-line trot in 220 lame horses (inclusion criterion: minimum 70% improvement in at least one movement asymmetry parameter after analgesia). The initial (before analgesia) lameness severity was based on the difference between vertical displacement minima or maxima of head (HDmin/max: Low 15-25 mm, Mid 25.01-35 mm, High 35.01-45 mm, V_High >45 mm) or pelvis (PDmin/max: Low 7-12 mm, Mid 12.01-17 mm, High 17.01-22 mm, V_High >22 mm). Linear mixed models were used for analysis – outcome variable: H_ROMz, W_ROMz or P_ROMz; random factor: horse; fixed factors: analgesia (before/after), initial lameness severity; covariate: speed (P<0.05). H_ROMz decreased by 15-37% with improved forelimb lameness and P_ROMz decreased by 6-23% with improved weight-bearing hindlimb lameness. The decrease was greater in more severely lame horses. With higher speed, H_ROMz decreased in hindlimb lame horses and P_ROMz decreased in all horses. W_ROMz increased with speed in weight-bearing forelimb lame horses only. Our results suggest that ROMz increases with lameness severity and decreases with increasing speed. Hence, normalizing asymmetry values to ROMz is discouraged.

Injury Risk factors associated with training and competition in flyball dogs

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Flyball is a fast-paced, high-energy canine sport which has received negative press regarding the potential for injury, and possible welfare implications for canine competitors. Whilst risk of injury associated with the sport has been investigated, evidence gaps still remain. An online questionnaire was distributed to over 3,000 members of the British Flyball Association in the UK, to obtain data on dogs that had competed in flyball in the last five years but remained injury free, and a second questionnaire obtained data on dogs that had also competed within the last five years but sustained an injury. Data relating to a dogs conformation such as height and weight as well as performance such as course completion time and equipment used was collected for 581 dogs, with the same data plus information relating to location and type of injury collected from an additional 75 injured dogs. Data were then compared using univariable, multivariable and multinomial logistic regression. The most common injuries were to the muscles of the shoulder back, whilst dogs completing a flyball course in less than four seconds had the highest level of injury risk (P=0.029), which reduced as time taken increased. There was an association between risk of injury and increasing age, with dogs over 10 years old most likely to be injured when partaking in the sport (P=0.004). Furthermore, dogs using an angle of flyball box of between 45 and 55° had a greater risk of injury, while using an angle between 66 and 75° reduced the risk of injury by 67.2% (OR: 0.328). Use of carpal bandaging was significantly associated with carpal injuries (P=0.042). These findings identify new risk factors for injury within flyball which can be used to improve welfare and safety for competitors.

The Effect of dynamic mobilisation exercises on equine movement symmetry

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Equine asymmetries have a high prevalence, with a frequency of up to 50%, in horses undergoing training and competing which could be detrimental to health and performance. Dynamic mobilisation exercises (DMEs) are proposed to have benefits for equine orthopaedic health and may reduce gait asymmetry. Movement symmetry (poll, withers, lumbar vertebra-1, tuber sacrale) was quantified with inertial measurement units (IMUs) in ten convenience sampled horses. Stride duration was also provided by the IMUs. All horses performed DMEs in a crossover design allowing comparison of control trot-ups to DME trot-ups. On day 1 group-2 received DME intervention prior to a trot-up, and group-1 performed a trot-up without DME intervention. After 8-days, these groups were crossed over. The DMEs were performed once immediately before the trot up by encouraging the horse's chin to chest, carpus, fetlock and chin to hip and tarsus. Each movement was held for 6-10 s. Linear mixed models tested for significant differences (P<0.05) between the symmetry parameters of horses performing DMEs and controls. Vertical displacement data indicated that the difference between the two pelvic Min-Diff significantly reduced by 2.4 mm following DME intervention (P=0.016). Additionally, DMEs affected poll by reducing upwards amplitude (Up-Diff) by 6.1 mm (P=0.031) and the withers Max-Diff increased by 1.9 mm (P=0.028). Lumbar vertebra-1 Min-Diff decreased following DMEs, from 4.4 to 1.3 mm (P=0.001), and a reduction in stride duration by 70.1 ms (P=0.031) was also seen following DMEs. This research suggests a reduction in poll, lumbar vertebra-1 and pelvic asymmetry may be achieved by performing DMEs.

Movement symmetry analysis for diagnostic analgesia use during clinical lameness examinations

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Diagnostic analgesia (DA) is commonly used for identifying the affected limb(s) and structures in lame horses. Movement symmetry analysis contributes to reducing expectation bias in this process. 191 horses undergoing DA during lameness examinations were included in the study. The effect of subjectively judged efficacy (negative, partially positive, positive) and type (4/6 categories respectively of forelimb/hindlimb DA; from case records) of DA on differences in three head and four pelvic movement symmetry parameters before/after DA were quantified. Primary and compensatory movement symmetry effects were investigated with linear mixed models with DA efficacy and DA type (and their interaction) as fixed factors (P<0.05; Bonferroni post-hoc correction). A significant two-way effect was found for forelimb DA for three head symmetry measures and one pelvic symmetry measure (contralateral asymmetry) (all P≤0.023). Positive forelimb DA showed larger changes (7-18 mm reduction in asymmetry) than partially positive (2-8 mm reduction) and negative (1-2 mm increase) forelimb DA. The largest improvement (13-16 mm) was found for the low4-point block. A significant two-way effect (both P≤0.02) was found for two pelvic symmetry measures for hindlimb DA. Hindlimb DA efficacy affected hip height difference and head minimum and upward amplitude difference (ipsilateral compensatory effects) (all P≤0.001) with the smallest improvement for tarsometatarsal joint DA. There was no difference between partially positive and positive hindlimb DA, which might be related to the subjectivity and interobserver variability of hindlimb lameness scoring 'by eye'. This is encouraging for further investigations in using automated pattern recognition approaches.

Compensatory vertical asymmetry of the head and withers in naturally lame dogs

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Previous research has shown the direction of head and withers vertical asymmetry can be used for distinguishing primary from compensatory fore-limb lameness in horses. However, it is unknown if the same compensatory mechanisms also occur in dogs. This study investigated the vertical movement asymmetry of the head and withers in 9 sound and 32 lame dogs (graded 1-4 (0-5 scale) by veterinarian visual assessment (15 fore-, 8 hind-, 9 mixed-limb [fore- and hind-])). An optical motion capture system was used to obtain minimum and maximum vertical displacement; range and symmetry index up and down, of the head, withers and sacrum. Shapiro-Wilk normality, Kruskal-Wallis and Dunn post hoc tests were run on absolute values, to quantify full range of displacement. This showed that the difference in head range down was the only significantly different parameter in forelimb lame dogs (M±SD [95%CI]) (13.92±10.30 mm [8.52 mm, 19.32 mm]) compared to sound dogs (5.40±4.39 mm [2.53 mm, 8.27 mm]) (P=0.04). Furthermore, 79% of forelimb and 78% of mixed-limb lame dogs showed unidirectional head and withers minimum displacement asymmetry confirming ipsilateral asymmetry, thus primary lameness. The mixed-limb lame group included forelimb lameness, which could explain the similar compensatory mechanism observed in forelimb lame dogs. The results support previous work in dogs identifying head lowering asymmetry as the most sensitive indicator of clinical forelimb lameness, and show that vertical displacement asymmetry of the withers has the potential to be used as a predictive measure to discriminate dog primary from compensatory forelimb lameness.

Locomotor and related behavioural patterns in osteoarthritic dogs using a collar-worn accelerometer

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Early detection of osteoarthritis remains the most effective method of managing osteoarthritis. This research aimed to measure locomotion patterns at walk, trot and sprint, and investigate their relation to ability to scratch and sleep behaviour in healthy and osteoarthritic (OA) lame dogs using an externally validated second-by-second dog activity tri-axial accelerometer worn at home for 2 months. The sample included dogs from 30 different breeds; OA dogs (n=30): mean age=9.06 years ±2.85 years and healthy matched control dogs (n=30): mean age = 8.83 years, ±2.94 years. Paired sample t-test or Wilcoxon test were conducted between OA dogs and controls. OA dogs walked (M±SD or Md; hours, minutes or seconds) (55.64±20.71 m) (P=0.008), trotted (2.72 m) (P=0.004) and sprinted (0.46 m) (P≤0.001) less on average in 24 hours, and started their nightly sleep earlier (22:05 (GMT)) (P=0.033), compared to matched controls (72.24±28.55 m; 10.16 m; 3.51 m; 22:15 (GMT), respectively). Forelimb OA dogs (n=10) scratched (43±25 s) less than controls (1.78±0.02 m) (P=0.034). Hindlimb OA dogs (n=11) trotted (2.38 m) (P=0.026) and sprinted (0.3 m) (P=0.006) less, and slept for longer (8.73±1.45 h) (P=0.040) than controls (10.48 m; 3.88 m; 7.63±0.88 h, respectively). Quadrilateral OA dogs (n=5) sprinted less (0.53 m) than controls (4.92 m) (P=0.043). The results showed changes in locomotor patterns, particularly quantity and type of gait and sleeping patterns for hind lameness, and reduced time scratching for fore lameness, suggesting less ability to normally scratch (i.e. not associated to a pruritic condition), in OA dogs compared to healthy dogs. These changes can be useful to build the necessary algorithms for early detection of OA lameness in dogs in household environments using a single collar-worn accelerometer.

Vaccination-associated lameness in warmblood horses after intramuscular injection

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The FEI states to wait at least seven days before competing after influenza vaccination. This requirement only considers the circumstance of immunity while effects of vaccination on asymmetries related to lameness are unexplored. This study investigates the effects of intramuscular vaccination on gait asymmetries in warmblood horses in two different vaccination sites. Fourteen horses were vaccinated against influenza with Equilis® Prequenza ($n_{experimental}$=8) or against influenza/tetanus with Equilis® Prequenza Te ($n_{experimental}$=6) and eight horses received a control injection (saline, 2 ml) in the left/right pectoralis ($n_{experimental}$=8/$n_{control}$=5) or semitendinosus ($n_{experimental}$=6/$n_{control}$=3) muscle at random. Measurements were performed using EquiMoves® (200 Hz). The horses were hand trotted on a straight line before (baseline) and at 8, 24, 48, 72 and 96 h after vaccination. Linear mixed models (random effect = horse, fixed effect = timepoint, α=0.05) were used to analyse the differences in upper body asymmetry between baseline and the different timepoints, for the pectoralis and semitendinosus muscle separately. There were no differences (P>0.05) between timepoints for the pectoralis muscle, or for the control group. For the semitendinosus group, PDmax significantly differed between baseline and 48 h (10.57 mm, P<0.001). Horses vaccinated in the semitendinosus muscle showed a transient push-off hindlimb lameness after 48 h. Although not all vaccination sites might show such an impact on gait, the results of the current study suggest that 48 h after the vaccination, a muscle soreness/pain is present. Therefore, we recommend not to exercise horses for at least 72 h after vaccination. Further research could quantify effects of other intramuscular vaccines on locomotion.

Session 7 – Horse-Saddle-Rider Interaction / Equitation Sciences

A preliminary study on the kinematics of monkey crouch riding at slow canter

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The purpose of this study was to quantify the kinematics in monkey crouch at slow canter between different riders. Two riders rode two experimental thoroughbreds with the monkey crouch. To observe slow canter trials, 20 OptiTrack motion capture cameras at 240 Hz were settled in the experimental track. 25 and 37 reflective makers were attached on the anatomical landmarks of rider and horse respectively. Then the centre-of-gravities (CG) of rider's upper, lower and whole bodies and horse were calculated. In this study, 2D model of the rider and horse was assumed on their sagittal plane. The fluctuation range of rider's whole body CG vertical velocity (-0.7 to +0.5 m/s) is smaller than that of the horse (-0.95 to +0.8 m/s). In addition, a phase difference existed between the rider's upper and lower body CG velocities, with the upper body CG velocity lagging about 0.04 sec behind the lower body velocity. This vertical oscillating movement of the upper and lower body CGs were carried out by flexion-extension or dorsi-plantarflexion of the rider's hip, knee, and ankle joints. Both rider's hip and knee angles oscillated at a double cycle for each complete stride of the horse. However, on one hand, angular velocities of those joints of the lead leg side had lagging the non-lead leg side of the horse with 0.05 to 0.06 s. Therefore, it was found that their monkey crouch riding was asymmetrical motion. On the other hand, from the view point of the joint angular velocity (ω)at the timing of the lead hind limb and the non-lead forelimb ground contact, one rider performed his hip flexion dominantly ($\omega_{hip}>\omega_{knee}$), the other performed his knee extension ($\omega_{hip}<\omega_{knee}$). The fact that asymmetry was observed even in monkey crouch and rider depending manoeuvre suggested that a wider survey of riders in the future will lead to an understanding of riding skills in monkey crouch.

Pelvic kinematics of riders performing rising trot on a simulator compared to riding overground

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Simulators are widely used in equestrianism, increasingly so for research. This study quantifies pelvic kinematics of riders performing rising trot on a riding simulator compared to those when riding overground. Ten right-handed experienced riders (35±7 years, 62±9 kg) performed a standardised ridden protocol on their own horse overground and rode a dressage riding simulator following an in-built pre-set programme. All riders wore an Xsens motion capture suit recording at 120 Hz. Rising trot data was extracted, exported, separated into diagonals, and analysed in SPSS using paired T-tests (significance $P \leq 0.05$). Cycles of motion were determined from vertical displacement data, commencing from the minimum value while seated, through the rise to seated again. On both diagonals, the relative phasing between rotations of pelvic roll, pitch and yaw differed between overground and simulator, with pelvic yaw being in phase, but roll being out of phase by quarter of a cycle, and pitch by half a cycle. Compared to overground, displacement amplitudes were significantly different on both diagonals, with greater values of roll and pitch, but less yaw on the simulator. When riding overground, riders demonstrated greater roll to the right on the left diagonal than when on the right diagonal (4.0 vs 2.5°, $P=0.005$) and less to the left (0.0 vs 1.4°, $P<0.001$). Rider pelvic kinematics differ when performing rising trot on a simulator compared to overground. Riders displayed displacement asymmetries overground but not on a simulator, suggesting some pelvic asymmetries may be influenced by the horse's motion rather than asymmetry of the rider themselves.

Thoracolumbar differential rotational movement of high-level horses in hand and in sitting trot

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Spinal kinematics differ between ridden and non-ridden horses. This study quantified differences in rotational movement of the thoracolumbar spine of among 21 elite dressage (6), showjumping (6) and eventing (9) competition horses trotted in-hand and ridden by their elite riders in sitting trot. Inertial measurement units quantified these differential rotational movements between adjacent sensors positioned at the following thoracic and lumbar vertebra and tuber sacrale: (T5-T13, T13-T18, T18-L3, L3-TS). Two general linear mixed models were created with discipline and condition or discipline and anatomic back segments and in-hand/ridden as fixed factors and horse as random factor (significance $P<0.05$). Ridden horses had a significantly higher differential roll rotation at L3-TS (21.9°) compared to all other back segments. Differential pitch rotation had the greatest range at T13-T18 in ridden (9.4°) and non-ridden horses (8.1°). Rotational movements were significantly greater in ridden trot for differential roll at segments T5-T13 and, T18-L3, and smaller at L3-TS ($P<0.001$) compared to in-hand trot; pitch was greater in ridden horses at T18-L3, L3-TS ($P<0.001$), while yaw was greater in ridden horses at T18-L3, but lower at T5-T13 and L3-TS than in non-ridden ones ($P<0.001$). There was no significant difference in any movement direction at the level of T13-T18 between ridden and non-ridden horses. Only differential yaw rotations at L3-TS were found to be significantly different ($P<0.001$) between dressage (3.2°) and eventing horses (6.6°), implying increased dynamic stability in dressage horses compared to eventers. The variations in movement between specific spinal segments can aid the understanding of pathology development and rehabilitation.

Effect of a half pad and shims on pressure distribution when used under a wide saddle

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Saddle fitters may fit a saddle wider than industry guidelines (Society of Master Saddlers (SMS)) and use a half pad to achieve correct saddle fit. Eight horses ridden by the same rider were recruited. Three qualified saddle fitters (SMS) fitted a correct width saddle (CWS), and a saddle which was one width fitting too wide (10 deg.) and corrected with a half pad (WS) and 13 mm closed-cell foam shims to each horse. A Pliance pressure mapping system was used to quantify mean/peak pressures (kPa) beneath the front/caudal regions of the saddle during straight-line walk, rising trot, 2-point trot and canter. Back dimensions were obtained immediately after CWS and WS using a flexible ruler shaped over the tenth thoracic vertebra (T10). The shape was traced onto graph paper, and the distance 3 and 15 cm ventral to the midline was measured. Data were analysed using paired t-test (parametric) or Wilcoxon Signed Rank test (non-parametric) ($P \leq 0.05$). For the WS compared to CWS, significantly higher mean front pressures (kPa) were found in walk (WS 14.2±1.7; CWS 11.0±1.8, $P=0.01$); rising trot (WS 10.9±1.7; CWS 9.1±2.2, $P=0.01$); 2-point trot (WS 18.0±1.6; CWS 16.2±3.0, $P=0.01$) and canter (WS 17.8±3.1; CWS 14.3±3.4, $P \leq 0.001$). No differences were found for caudal mean saddle pressure or front/caudal peak pressures (all $>P=0.07$). Back dimensions at T10 were significantly reduced ($P=0.03$) for the WS (15 cm: 29.8±1.43 cm) compared to CWS (31.2±2.4 cm). A wide saddle corrected with a half pad/shims may increase mean pressures in the front region of the saddle and affect back dimensions.

Do noseband type and tightness affect pressure distribution beneath the noseband when ridden in trot

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The effects of noseband type and tightness on facial pressure are poorly described. This study quantifies pressure simultaneously over the nasal bones (nasal) and the mandibular rami (mandibular) for four noseband types fitted at five tightness levels. Four advanced dressage horses, evaluated subjectively to be free from lameness, were ridden by three advanced riders. Two small pressure mats (Pliance, 160×80 mm) were positioned between the noseband and the nasal bones and between the noseband and the mandibular rami. With all bridle features remaining the same, a cavesson/crank/flash/drop noseband was fitted in a random order to each horse by a qualified bridle fitter. Noseband tightness was adjusted using an ISES taper gauge increasing tightness by 0.5 finger increments (2/1.5/1/0.5/0 fingers). Nasal and mandibular mean noseband pressures were recorded for 10 strides as horse/rider trotted in a straight line. Data were analysed using two-way and one-way Anova with Bonferroni post hoc tests ($P<0.05$). Mean nasal pressures (kPa) influenced by noseband tightness ($P=0.0004$) were 2, 1.5, 1 vs 0 fingers and 2 vs 0.5 fingers (all $P<0.01$). With the noseband adjusted to 0 finger tightness, mean nasal pressures were 6.7 kPa drop, 10.8 kPa cavesson, 14.4 kPa flash and 14.4 kPa crank. Mean mandibular pressures influenced by noseband tightness ($P=0.0004$) were 2, 1.5, 1 vs 0 fingers and 2 vs 0.5 fingers (all $P<0.004$). With the noseband adjusted to 0 finger tightness, mean mandibular pressures were 14.5 kPa cavesson, 13.5 kPa flash, 19.9 kPa crank.

Noseband type and tightness: effect on eye temperature and blink rate standing and eating a treat

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Equine eye temperature and blink rate have been used as potential indicators of stress. The objectives were to quantify eye temperature (ET) and blink rate (BR) in horses fitted with different noseband types and tightness. In a cross-over design, a cavesson, crank, flash, drop and no-noseband were fitted to four unridden advanced dressage horses. Noseband tightness was adjusted using a modified (with 0.5 finger increments) ISES taper gauge with tightness starting at 2 fingers, increasing by 0.5 finger increments to 0, each maintained for 237 s maximum. Horses were measured standing square and chewing a treat. An infrared thermal camera quantified ET (°C) at the medial canthus at three-time points: baseline (B), immediately after noseband tightening (T), and end of 20 s trial (E). BR was recorded per minute throughout. Data were analysed using Wilcoxon and Kruskall-Wallis with post-hoc Mann-Whitney U tests ($P<0.05$). While standing, the action of noseband tightening had no effect on ET ($P\geq0.05$). ET at E was lower for cavesson (mean±SD: 32.4±0.5°) than drop (33.2±0.3°), crank (33.3±0.6°), no noseband (33.1±0.3°) and baseline (33.9±0.0°)($P<0.05$). While chewing, noseband tightness and type had a significant effect on ET at T and E ($P<0.05$). Cavesson (T:32.6±0.9°, E:32.6±0.7°) was lower than crank (T:33.0±0.3°, E:33.0±0.4°), drop (T:33.0±0.5°, E:33.0±0.7°), and no noseband (T:33.5±0.4°, E: 33.0±0.7°, $P<0.01$). Flash ET (T:32.8±1.0°, E:33.1±0.3°) was lower than no noseband (T:33.5±0.4°, $P=0.0001$, E:33.0±0.7°, $P=0.003$). BR did not differ between noseband type or tightness for standing or treat condition ($P>0.05$). The cavesson was associated with the lowest ET both standing and chewing.

Effect of noseband tightness on facial pressure during standing and chewing

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Little information is available describing the relationship between noseband tightness and facial pressure. The objective was to compare dorsal nasal and ventral mandibular pressures associated with a cavesson noseband adjusted to different tightness. Four dressage horses were equipped with two small pressure mats (160×80 mm, 1.5 mm thick, 64 sensors/mat) mid-dorsally (nasal) and mid-ventrally (mandibular) beneath a cavesson noseband fitted by a qualified bridle fitter. Noseband tightness was adjusted between 2 to 0 fingers in half-finger increments (2/1.5/1/0.5/0 fingers) using an ISES taper gauge. Noseband pressures were recorded for 10 s while horses stood still with the head-neck in a neutral position and for 10 s while chewing a treat. Data were analysed using Wilcoxon signed rank test (2 groups) and Friedmans with post hoc Wilcoxon (3 groups) with $P<0.05$. Mean pressures increased from 2 to 0 finger tightness for nasal (standing: 0.70 to 8.30 kPa; chewing: 2.78 to 14.56 kPa) and mandibular (standing: 1.15 to 12.21 kPa; chewing: 3.40 to 16.57 kPa) locations. Mean nasal and mandibular pressures differed between tightness levels when standing ($P=0.004$) and when eating ($P\leq0.007$) with 2.0 and 1.5 fingers having lower mean pressure than 0.5 and 0 fingers in both locations. The results confirmed that tighter nosebands generate higher facial pressures. Chewing was associated with higher mean pressures than standing, particularly on the mandibles. Even so, horses readily accepted and chewed the treats, suggesting the pressures were not aversive. Although research has focussed on nasal pressures, these measurements indicate the importance of mandibular pressure.

Take-off velocity determines jump angle over a 1.10 m vertical fence

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The take-off phase of a jumping effort determines the horse's trajectory over the fence and contributes to the success of the jump. Principles of projectile motion dictate that take-off velocities influence the trajectory of the jump. To our knowledge there is no normative data on the relationship between take-off velocity and take-off angle which can assist riders in their approach to training a horse. It was hypothesised that the horizontal and vertical velocity of the sternum marker would influence the take-off projection angle. Six horses were ridden by their own riders three times over a 1.10 m fence at right lead canter. The marker placed on the horse's girth was tracked with eight motion capture cameras (200 Hz) to determine 3D displacement, velocity, and its resultant. Take-off was determined as a feature in the resultant velocity relating to hind limb stance. Vertical, horizontal, and resultant velocities at take-off and take-off angle were calculated from kinematic data using the equations of projectile motion. Correlations between variables were tested using Pearson's correlation. Horizontal velocity was significantly positively correlated with the resultant velocity (r=0.97, P=0.001). Vertical velocity was significantly positively correlated with take-off angle (r=0.93, P=0.001). Horizontal velocity is influenced by the speed of approach and would necessitate greater braking impulse by the forelimbs to reverse the orientation of the horse's trunk for hindlimb push-off. Increased vertical velocity creates a steeper take-off angle. These results suggests that to influence the shape of the jump riders should focus on increasing vertical velocity.

Evaluating determinants of rider performance in high-level dressage riders

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Many factors influence the overall score for a dressage test, which makes it challenging and complex to establish key performance determinants. The aim was to identify an objective locomotory measure to quantify overall rider performance in dressage. The chosen variable should be both easy to collect and useful in a practical context. Twenty dressage horse/rider combinations (Int1-GP) were equipped with inertial measurement units (IMU's, 200 Hz) attached to the rider's sacrum and thorax. Transverse dynamic trunk symmetry and pelvis symmetry (symmetry measures) and trunk-to-pelvis 3-dimensional coordination variability (within rider coordination measure) were collected from the IMU's during straight line walk, trot and canter on left and right reins with ≥9 strides/condition. Sixteen United States Dressage Federation senior judges evaluated the movements of interest from video footage with 2-3 judges scoring each rider's performance in the movements of interest and awarding collective scores to represent the overall impression of each rider's performance. Stepwise linear regression was used to seek associations between objective measurements from the IMUs and subjective scores awarded by the judges. The variable dynamic trunk symmetry was the strongest predictor of collective scores, specifically the score for rider position (R=0.357, P=0.001). The rider's dynamic pelvic symmetry was a strong predictor of the judged score for the walk (R=0.607, P=0.010), but no relationships were found between objective and judged scores for trot or canter. The overall impression of trunk posture may be influential in judges' collective scores. Symmetrical pelvic motion appears to be a key factor in producing a high-quality walk.

Pilot study of locomotor asymmetry in unridden and ridden horses walking on a circle

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To equestrians, straightness is a long-term training goal and equine laterality a concern, but associations to biomechanical asymmetries is unclear. This study quantified movement symmetry in walk on 9 m circles. Fifteen horses of different breeds, 6-24 years old, were measured with and without their usual rider (varying skill levels) using optical motion capture (150 Hz, ≥13 strides per trial, mean speed 1.25 m/s). Vertical motion symmetry (MinDiff, MaxDiff) for head (H), withers (W) and pelvis (P), pelvic roll, pitch, and yaw and tarsal, stifle and hip joint angles were calculated per stride. Associations to direction, whether ridden, and owner-perceived laterality (hollow side) were investigated using mixed models (including speed) and iterative k-means clustering. Direction was significant for 9 of the 12 variables (P<0.05). Thirteen horses were deemed lateralised, 7 left- and 6 right-hollow. For these, hollow side was significant (P<0.003) for PMaxDiff, HMinDiff, pelvic roll, hip and tarsal ROM. Left-hollow horses had greater pelvic roll in left (8.7°) vs right (8.2°) direction. Left-hollow horses had smaller inside and greater outside hip ROM in left (inside 17.0°, outside 21.8°) vs right direction (inside 18.9°, outside 20.1°, P≤0.0002). Pelvic roll ROM was the most influential variable for agreement between cluster groups and subjective laterality. In horses walking on a circle asymmetries suggestive of both individual and group-level laterality can be found. Only a subset of these are linked to rider perceived hollow and stiff side, suggesting that some patterns have bigger influence on the horse's performance in training than others.

Trunk kinematics of riders performing rising trot on a simulator compared to riding overground

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The use of riding simulators for research is becoming more common. This study compares trunk kinematics of riders on a riding simulator to those riding overground while performing rising trot. Ten right-handed experienced riders (35±7 years, 62±9 kg) performed a standardised ridden protocol on their own horse overground and rode a riding simulator following an in-built pre-set programme. All riders wore an Xsens motion capture suit recording at 120 Hz. Sternal/T8 sensor data was extracted, exported, separated into diagonals, and analysed in SPSS using paired T-tests (significance P≤0.05). Cycles of motion were determined from vertical displacement data, commencing from the minimum value while seated, through the rise to seated again. Comparing overground to simulator, the relative phasing between rotations of trunk roll, pitch and yaw demonstrated corresponding patterns of displacement on the left diagonal but on the right diagonal roll was out of phase by half a cycle (opposite). Displacement amplitudes were significantly different with greater values of roll on the simulator (6.2 vs 3.4°), but greater pitch (12.9 vs 9.6°) and yaw (6.2 vs 5.2°) overground. Riders demonstrated greater trunk roll to the right than left on both diagonals when on the simulator and overground (all P<0.002). Compared to overground riders displayed significant differences of 5.0° less trunk extension on the simulator on both diagonals (P=0.002 both diagonals) and 2.7° greater flexion on the left diagonal (P=0.047). Results suggest that caution is required when using simulators to analyse rider trunk kinematics as some differences in pattern and amplitudes of displacement exist.

Session 8 – Riding/Racing Surface/Hoof

Jockey position and surfaces affect kinematics and coordination in trotting racehorse-jockey dyads

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Racehorses routinely trot over varied terrain to access gallop tracks and warm-up. Understanding how jockey position influences racehorse movement may have a bearing on safety and stability, and this may vary across surfaces with contrasting fundamental properties, including hardness and regularity. This study used inertial sensing technology (Werkman Black hoof sensors, XSens MTw sensors) and linear mixed models to quantify and determine the significance ($P \leq 0.05$) of surface type (tarmac, artificial, grass) and jockey position (rising, two-point seat) on: (1) duration of different stride cycle stages; (2) horse movement symmetry; and (3) horse-jockey temporal coordination. Six ex-racehorses were convenience sampled from the British Racing School and were ridden by one jockey. Statistical models included speed or stride duration as a covariate. Hoof landing duration was 4.3-4.5 times shorter on tarmac compared to grass and artificial ($P<0.001$). Mid-stance was 19 ms longer on tarmac compared to artificial ($P<0.001$), while swing lasted 20 ms longer on grass compared to artificial ($P<0.036$). Mid-stance increased by 13 ms for two-point seat compared to rising ($P=0.013$). Stride length decreased by 14 cm on tarmac compared to grass ($P=0.047$) and correlated positively with speed ($r^2=0.8$, $P<0.001$). Withers asymmetry across stance phases (MinDiff) increased on artificial and grass compared to tarmac ($P \leq 0.043$) and pelvic MinDiff was also higher on artificial compared to tarmac ($P=0.048$). Poll asymmetry was high across flight phases (MaxDiff, UpDiff) on grass and MaxDiff/UpDiff at L1, withers and pelvis increased for rising position. Time offsets between horse-jockey movements increased by 2.8-4.5% at stance with the jockey out of saddle.

Bias in the lateral movement of the equine jump

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Whilst the equine jump has been studied in the sagittal plane, there is limited information about movement in the transverse plane. Lateral movement during jumping was quantified and modelled against equine jumping biomechanics. 4 mares and 4 geldings fitted with anatomical markers, were video recorded loose jumping a grid exercise of three fences along a wall, culminating in a central vertical fence (0.8-1 m). Horses jumped the grid three times in both directions; starting direction was randomized (mean (± SD) speed: 7.2 (±0.79) m/s). Lateral movement was quantified in the transverse plane from forelimb push-off to hindlimb landing, using Simi motion 2D®. Pearson's correlation investigated the effect of age. Population biases and sex differences were assessed using two-sided *t*-tests. Gaussian general linear models modelled lateral movement in relation to limb positions at take-off and landing and equine linear kinematics. Horse was not included as a random factor as it decreased model fit. All horses displayed lateral movement during jumping with a significant bias towards the right (P<0.0001), in both directions. Horses drifted right over 96% of jumps, demonstrating a mean (± SD) displacement of 0.24 (±0.2) m. A negative trend was observed between lateral movement and age (P=0.055), and mares drifted significantly more than geldings ($Sex_{(g)}$ R^2=-0.168, P<0.001). Significant relationships were found between lateral movement, forelimb positions at take-off and landing (P=0.015; P=0.004), and wither height during suspension (P=0.022). Horses displayed significant lateral movement when jumping, influencing jump paths and footfall patterns with potential performance and health consequences.

Damping material placed underneath sand on a track reduces the limb's loading rate at training speed

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The effects of modifying the deep part of a training track are poorly documented. The objective of this study was to compare dynamic variables in the forelimb of one harness horse trotting on two surfaces only differing by the introduction of damping material underneath sand. A French trotter gelding (476 kg) was used. His right fore hoof was equipped with a dynamometric horseshoe composed of 4 triaxial piezoelectric force sensors (Kistler-9251A), and a triaxial piezoelectric accelerometer (PCB-356B20) fixed to the dorsal hoof wall. A wifi-connection enabled to remote-control data acquisition (7.8 kHz). Speed was recorded by means of a third wheel equipped with a hub-dynamo. The horse repeated trials alternately on two parallel corridors delimited on a traditional crushed sand track; on the 'D corridor', 3 cm of a damping material (rubber derivative) was placed underneath 13 to 15 cm of sand. The target speed was 40 km/h. Linear mixed-effects regression models were used (SAS; P<0.05). 90 (D) and 80 (reference corridor) strides were analysed. Speed was not significantly different between corridors. Maximum deceleration peak at impact was not either; however density of 50 to 400 Hz vibrations was lower on D (P=0.001), as well as stride length (P=0.002). Vertical loading rate at maximal loading was significantly lower on D (P=0.001). Although maximal vertical force tended to be lower on D, the difference was NS. Although performed on a single horse, this study demonstrates that a thin layer of damping material underneath the first 13-15 cm sand layer is enough to reduce the loading rate of the forelimb under training conditions.

An investigation of forehoof kinetics in young foals at walk

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Previous force plate (FP) studies have focused on adult horses while kinetics data in foals is missing. Our objective was to analyse and compare kinetics values at the impact (IP), midstance (MS), and breakover (BO) phases of walk. Four 10-12-month Arabian foals (average wither's height 132±4.7 cm, average weight 254±33.5 kg) with no apparent gait abnormalities were walked across a FP. Foals' walk on the FP was videotaped and speed was calculated about 1 m/s. A minimum of 3 valid trials were collected for both forefeet. Data were sampled at 1000·Hz and front feet vertical, (Fz), longitudinal (Fy), and transverse (Fx) forces as well as vertical impulse (VI) and centre of pressure (CoP) were measured. Left and right forefeet data were not statistically different (P>0.186). Statistical Differences (P<0.05) were analysed using Friedman's test and Wilcoxon signed rank test for post-hoc analysis. Average normalised Fz at the IP, MS, and BO phases were 6.346, 7.598 and 5.653 N/kg, respectively. Overall Fz varied among the three phases (P=0.0002). Fz at BO was different from both IP (P=0.008) and MS (P=0.008) phases, and IP and were different (P=0.016) from MS phase. VI also varied among phases (P=0.0006). VI at IP differed from VI at MS and BO phases (P=0.008) but it was not different between MS and BO (P=0.055) phases. CoP did not significantly differ among any of three phases (P=0.778). This study used a limited sample size (n=4), nevertheless, it reports hoof kinetics at different phases of the gait in foals at walk.

Effect of open shoes and frog support bar shoes on hind feet in six show jumping horses

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This study compared the angle of orientation oft he hind hooves at midstance in 6 Showjumpers with standard shoes and with frog support hind shoes. This review summaries current knowledge in farriery and focused the aim to measure and compare the angle of orientation at midstance phase of the horses stride. The study took place under realistic conditions with six show jumpers on a sport arena surface. High tech tools (Ontrack Equine Tracking Software) were used to identify results from the moment of impact during high-speed locomotion video capture (Optronis 500 frames/sec) from every horse/jump. Measurement results and statistics identified differences in the horse sample size. The Mann-Whitney test showed that the average angle of orientation with open hind shoes, at 5.1°, changed to an average of 11.3° with frog support bar hind shoes. The importance of the interaction between horse and shoe type for subsequent sport abilities, such as in show jumping, was shown in this and many other work. The frog support bar shoe increase the angle of orientation (plantar P3 angle) significantly. These findings can be used to develop sport horse farriery science, biomechanics oft the horse, physical training, reduce injury and benefit the athletic horse.

Evaluation of hoof pressure and contact area using Fujifilm® in booted and shod horses

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Evaluating hoof load is important when choosing a riding terrain. The objective of this study was to determine if Cavallo Trek hoof boots (HB) could lessen the pressure (P) and distribute a horse's weight over a larger surface area (CA) than a metal horseshoe (HS) or a metal horseshoe with Equi-Pak pour-in pad (HS-EP). Five mature horses (491±37 kg; 17±5 yrs.) were used for quantification using Low Prescale Film (Fujifilm, Sensor Products, Inc., Madison, NJ, 2.4×10^6 to 9.6×10^6 Pascals) on asphalt. Two replicate hoof prints per horse per treatment were collected by placing the left front hoof of each horse onto the film and transferring its full weight onto that limb. Pseudocolor imaging using Topaq software revealed variation in P and CA. One-way ANOVAs were used to evaluate the effect of treatment on P and CA and the means were separated using Tukey Multiple Comparison tests. P was significantly less (P<0.05) for HB than HS and HS-EP, with a mean difference of 658 and 724 kPa, respectively, but no difference was detected between HS and HS-EP (65.5 kPa; P=0.94). CA was significantly greater (P<0.001) for HB than HS and HS-EP, with a mean difference of 3.11 and 3.37 cm^2, respectively, but no difference was detected between HS and HS-EP (0.26 cm^2; P=0.5). The HB lessened pressure and distributed more of the horse's weight over a larger surface area than the other two treatments. This warrants investigation in the moving horse to confirm that similar trends exist.

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