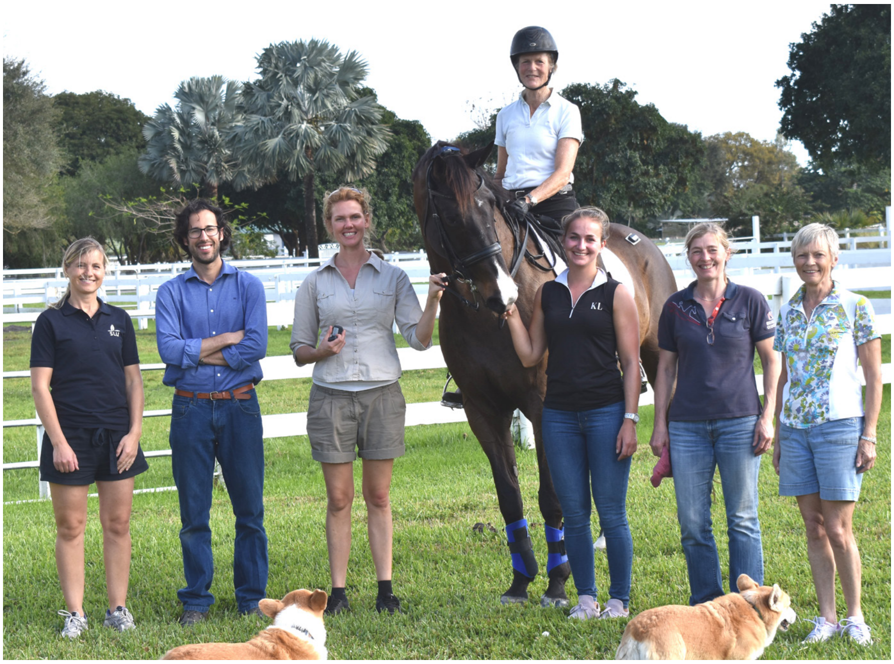
The Florida Project

In 2011, researchers used wearable sensors to study dressage horses' movement. This year, the study continued—and has exciting implications for training, riding, and lameness diagnosis.

By Hilary M. Clayton, BVMS, PhD, Dipl ACVSMR, FRCVS

I've been doing research on equine biomechanics since the 1980s, and during that time there have been incredible advances in equine-locomotion analysis.



RESEARCH TEAM: Dr. Marie Rhodin, Dr. Filipe Bragança, Dr. Elin Hernlund, Rosalie Bos, Dr. Sarah Jane Hobbs, and Prof. Hilary Clayton with rider Kim Aikens on Horbjergards Ziggy during the January 2020 data-collection project in Florida

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Today's technology can evaluate a horse's gaits, monitor changes in movement patterns as training progresses, and detect subtle signs of asymmetry or lameness before they become visible to the human eye. What's more, this information can be available almost immediately after making a recording.

One of the important scientific advances in locomotion analysis has been the development of wearable sensors that can be used both on horses and riders (in this article, I'll use the generic term *inertial sensors* to describe these measuring devices). One such device, the Equinosis Q Lameness Locator, is used by veterinarians to determine which of a horse's limbs is lame, and to what degree. The Lameness Locator uses inertial sensors that are placed on top of the croup, on the poll, and on the right front pastern. The pastern sensor detects movements of the right forelimb, which enables the system to distinguish between left and right steps and diagonals. The croup and poll sensors detect asymmetries in the vertical movement patterns relative to movements of the left and right limbs and diagonals. The data are transmitted to a tablet or laptop, and custom software evaluates any differences in minimal or maximal heights of the croup and poll on the left and right diagonals. Results are displayed as numbers and graphs, from which the veterinarian can discern right and left front- or hind-limb lameness.

Phase 1: The Florida 2011 Project

In 2011, researchers from the Mary Anne McPhail Equine Performance Center at Michigan State University partnered with Dr. Thilo Pfau from the University of London to study how the symmetry of the horse's trot changes on a circle compared with on a straight line. The study used Equigait, an inertial-sensor system developed by Dr. Pfau.

The results showed that when sound horses trot on a circle, their gait becomes asymmetrical in such a way that it mimics lameness of the inside forelimb and inside hind limb. The amount of asymmetry increases at faster trotting speeds and on smaller circles. The sensors were sensitive enough to detect differences even on a large (20-meter) circle.

This is important information for veterinarians because the effects of circling are enough to make a sound horse appear bilaterally lame when evaluated in both directions. A mild lameness may be exaggerated when the affected limb is on the inside of the circle, but it may be neutralized with the lame limb on the outside of the circle.

Further Development of Inertial-Sensor Systems for Lameness Analysis

Since the 2011 study was published, there has been a tremendous amount of research into the use of inertial sensors to measure gait asymmetries

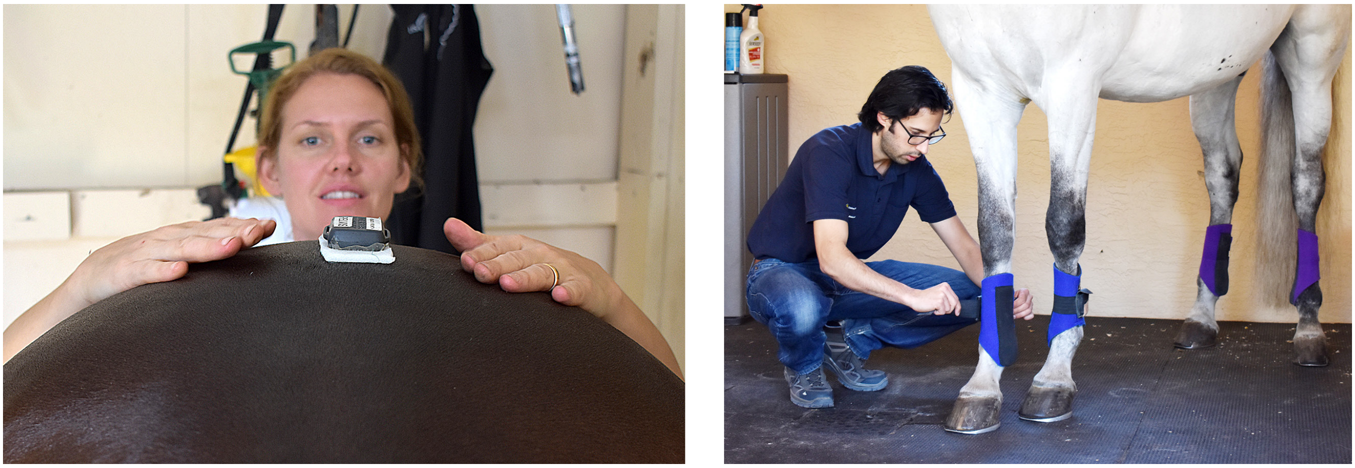

FIGURE 1. The EquiMoves system uses small inertial sensors that attach to the horse using adhesive pads. At left, Dr. Elin Hernlund centers a sensor over a horse's pelvis. At right, Dr. Filipe Bragança puts on brushing boots containing pockets for sensors that will measure movements of the cannon bones.

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in relation to lameness. Horses have been studied on the straight and on circles, on hard and soft footing, with and without riders, at sitting trot and at posting trot. No person or horse is completely symmetrical on both sides, and one of the researchers' tasks has been to establish reference values to delineate the inherent asymmetries that might be present in a sound horse from those associated with a mild lameness. In reality, though, there is not a sharp dividing line between horses that have a strong natural "sidedness" preference and those that are mildly lame.

But many unanswered questions remain, especially in the area of sport-horse performance. There is huge potential for inertial-sensor systems to be used to evaluate dressage horses' gaits, movement, and asymmetries. Doing so will require research to determine the most relevant performance parameters, followed by the development of software that will automatically crunch the numbers so that the relevant information is available right away. This is our current goal. The information will facilitate comparison of horses with different strengths and weaknesses, evaluation of a young horse's potential, assessment of the results of training, or detection of a deterioration in performance due to a developing but as-yet invisible problem.

Phase 2: Florida 2020

The next step in the progression of our dressage project requires the establishment of a database of locomotor information from high-quality dressage horses that are trained to a medium or advanced level, preferably ones that are also actively competing in the sport. In January of this year, an international team of top researchers (see "Meet the Researchers" on page 35) gathered in Wellington, Florida to collect data.

> **THE EFFECTS OF CIRCLING ARE ENOUGH TO MAKE A SOUND HORSE APPEAR BILATERALLY LAME.**

Researcher Filipe Bragança has been involved in developing a sensor system called EquiMoves, which uses the latest technology combined with custom software. The EquiMoves system has already been programmed extensively for equine-lameness detection and analysis.

EquiMoves captures information from up to 36 synchronized inertial sensors that can be attached to the body and limbs of horse and rider to measure movements and rotations (Figure 1). The system collects data continuously for several minutes as the horse moves freely over a large area. Because the information is three-dimensional, it can be applied to evaluate turns and lateral movements as well as locomotion in straight lines.

In order to get similar data from all horse-rider combinations, we wrote a test pattern that included all gaits on straight lines and on circles of different sizes on both reins. The pattern also included shoulder-in, travers, and shallow and steep half-passes in trot and canter; flying changes singly and in sequence; and pirouettes, piaffe, and passage. We collected data from 21 horses, 13 of which were capable of all the Grand Prix-level movements. The others performed as many of the movements as the rider was comfortable with.

We placed sensors on each horse's poll, withers, lumbar spine, croup, hips, all four cannons, and all four hooves (Figure 2) to produce a complete picture of the important movement characteristics. We also placed sensors on each rider's pelvis and trunk to record synchrony between horse and rider and to elucidate how experienced riders move

FIGURE 2. Sensors attached to all four limbs. Sensors on the cannon bones are securely attached in brushing boots. Hoof sensors are taped directly onto the hooves, then covered with tape for extra protection.

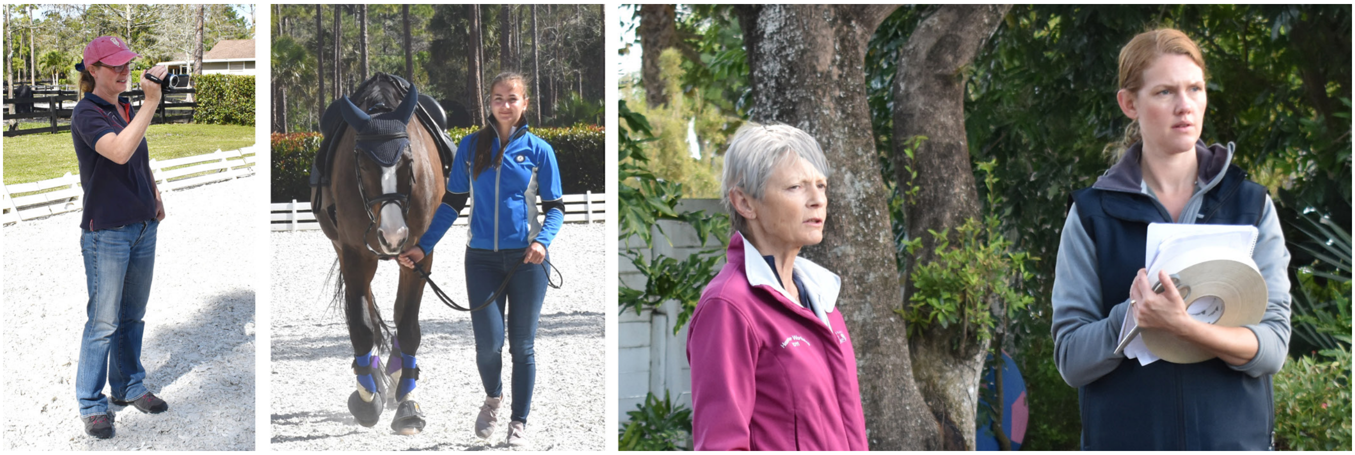

FIGURE 3. Sensor data and synchronized video being recorded at the start and end of the study as horses walked and trotted in hand in straight lines as in a lameness examination. Researchers compared minor gait asymmetries at the start and end of the study to identify any improvement or deterioration.

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in relation to the horse. Each horse was walked and trotted in hand as in a lameness examination, both before and after the ridden test. This phase of the evaluation was recorded on video and observed by the researchers, and any visible abnormalities were noted (Figure 3).

The rider mounted, and all the equipment was checked (Figure 4). After warming up, each horse performed the test pattern while recording data from the EquiMoves sensors and three synchronized video cameras placed around the arena (Figure 5). The videos will be evaluated to assess the quality of the gaits and movements and to identify problems or mistakes in the performance. Our goal is eventually to develop a complete picture of the biomechanics of an excellent performance as well as of the mechanical problems associated with specific errors in technique, such as “toe tapping” in passage.

Using lameness-analysis software developed for use with the EquiMoves system, we were able to discuss with each rider any asymmetries in the horse’s movement pattern during the trot-up in hand. For example, we could tell whether one hind limb was pushing more than the other, or if one forelimb was less effective in supporting the withers. We also evaluated whether movement asymmetries improved or deteriorated during or after the ride.

What We Will Learn

When I think about the range of data we collected and start to envision what could be done with it, I feel like the proverbial kid in a candy store. The need to evaluate results and develop software in a logical order will dictate, to some extent, which aspects of performance will be studied first. Here are some of the topics that are on the agenda.

Purity of the gaits. One of the issues that needs clarification in the era of the modern sport horse is how purity of the gaits should be defined. The traditional method involves evaluating the time intervals between successive footfalls: The pure walk is described as having a regular four-beat rhythm, the pure trot as having a two-beat rhythm (implying synchronous contacts of the diagonal limb pairs), and the pure canter as having a three-beat rhythm. However, slow-motion video has revealed that horses often do not have synchronous diagonal footfalls in trot or canter. In trot, horses that move in self-carriage in an “uphill” frame are more likely to

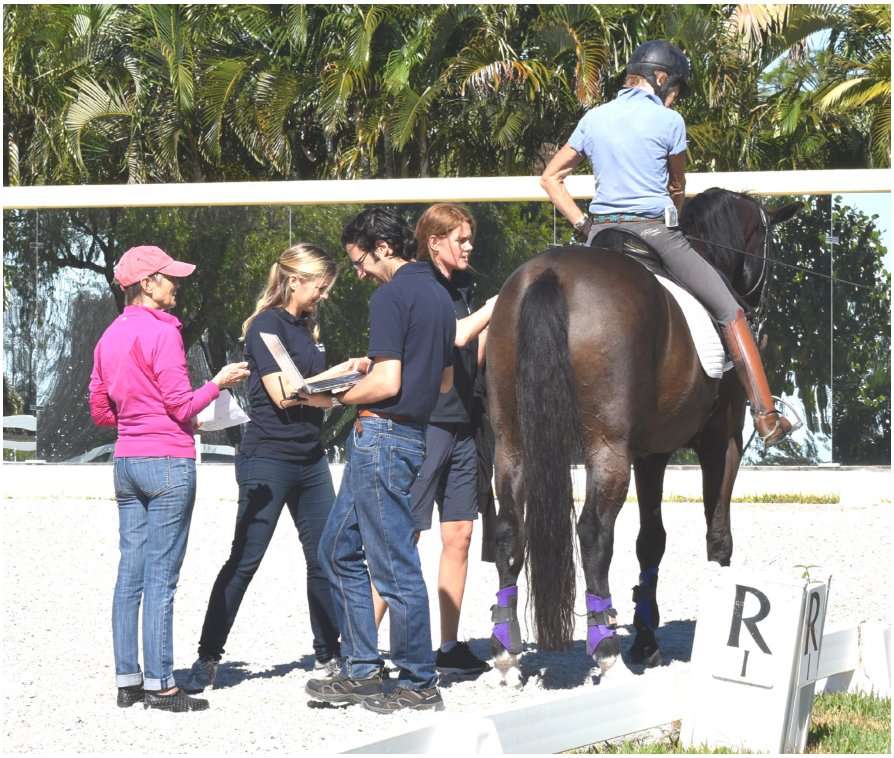

FIGURE 4. It takes a village! Final preparations for the ridden test included checking that all sensors on horse and rider were attached securely, and transmitting data to the laptop.

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have hind-first diagonal dissociation (with the hind leg landing a fraction of a second before the corresponding diagonal foreleg), whereas those that are on the forehand more often have fore-first dissociation. This is simply a consequence of whether or not the horse is in an uphill balance.

Perhaps of more fundamental importance to gait purity is the way that the movements (protraction and retraction) of the fore and hind limbs are coordinated, as this is a more basic determinant of limb movements and synchronization. The inertial sensors on the cannons and hooves will clearly indicate when the hooves contact and leave the ground as well as the transitions between limb protraction (forward swing) and retraction (backward swing). Coordination between the swing phases of the hind limb and forelimb may be a good indicator of gait purity.

Left- and right-sided horses. Postural and gait asymmetry (crookedness) are currently hot topics among locomotion researchers. As part of our study, the riders completed a questionnaire about their horses' sidedness patterns, and the inertial sensors will provide information about left/right movement asymmetries.

Vertical-movement asymmetries of the poll, withers, and croup have already been studied in detail in

HORSES OFTEN DO NOT HAVE SYNCHRONOUS DIAGONAL FOOTFALLS IN TROT OR CANTER.

relation to lameness, and threshold values for detecting lameness have been established for the trot. Smaller asymmetries may indicate a horse's sidedness pattern. In some preliminary studies, we have detected other signs of sidedness that will be measured precisely by the inertial sensors and cross-checked with the riders' opinions. These include:

- Failure to track straight (the hind limbs do not follow the tracks of the forelimbs)
- One forelimb supports the withers in a higher position than the other
- One hind limb remains on the ground longer, moves forward more slowly, and/or takes a shorter step than the other hind limb
- Inequality of minimal height of the croup, withers, or pelvis (thought to represent differences in loading of the left and right limbs); and differences in maximal height (thought to represent differences in push-off forces in the left and right limbs)
- Unequal left and right steps in passage and piaffe.

Ultimately, this part of the project aims to define the characteristics of a left-sided horse and a right-sided horse in biomechanical terms, then to associate the biomechanical findings with what the rider feels. We then will be able to design training exercises to improve locomotor symmetry and straightness based on an individual horse's entire set of asymmetries. This will be a step toward reducing the frequency and severity of having long steps alternate with short steps in piaffe and passage.

How does the horse achieve uphill self-carriage? The dressage rules are clear that collection and self-carriage require the horse to lower and engage its hindquarters for the benefit of the lightness and mobility of its forehand. But if the hind hooves are placed too far forward, it shortens the base of support excessively and impedes the horse's balance. Data from our study will provide information from a range of horses of various breeds, conformations, and skill levels that will help us to identify optimal hind-limb placement and whether it differs according to conformation.

The role of the forelimbs in elevating the withers to achieve uphill

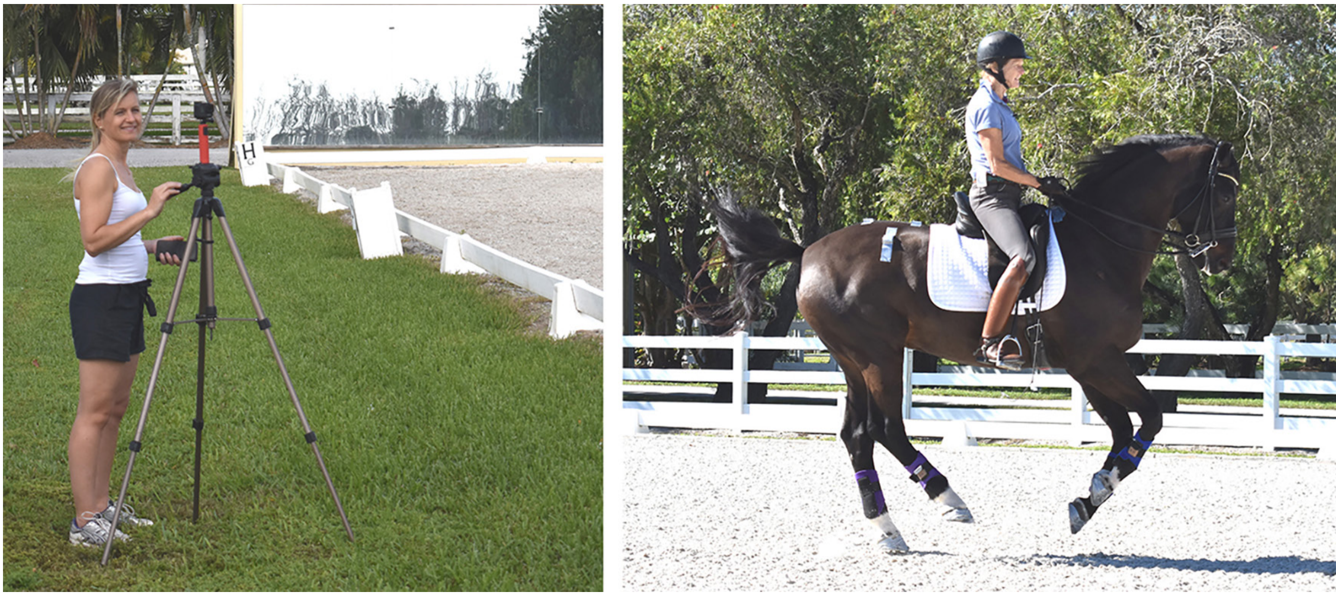

FIGURE 5: The ridden pattern was recorded videographically from three vantage points.

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balance has received less attention than the role of the haunches, but the forelimbs are equally important. Research in the McPhail Center has shown that withers height does indeed change with collection, and that the action of the forelimbs is a crucial part of the horse's ability to balance in the highly collected movements. Our findings will help us to understand the relationship between the positioning and timing of the fore and hind limbs in achieving collection.

Previous studies have shown that the collecting effects may not be identical in the left and right diagonals, and this makes it difficult for the horse to maintain balance consistently. We will investigate how this relates to the general sidedness pattern of the horse and which exercises can be used to improve balance and symmetry, especially in piaffe and passage.

Turns and lateral movements. We know that body and limb alignments are important in turning. Horses naturally turn by leaning inward, which facilitates the development of turning forces. A dressage horse must learn to keep its trunk and limbs vertical while bending its spine in the direction of the turn—fundamental skills that require the use of different muscles (abductors, adductors, abdominals, and back muscles) to negotiate the turn. After strengthening these muscles, the horse can make tighter turns while maintaining the correct alignment. Our inertial sensors will provide information about the verticality of the limbs, the haunches, and the forehand, thus providing a picture of the position and alignment of all parts of the body.

WE WILL BE ABLE TO DESIGN TRAINING EXERCISES TO IMPROVE STRAIGHTNESS BASED ON AN INDIVIDUAL HORSE'S ASYMMETRIES.

The horse's verticality and longitudinal straightness are fundamental to successful dressage performance. Through developing a better understanding of how individual horses achieve this and recognition of the common deviation patterns, it will be easier to prescribe specific gymnastic exercises to straighten the horse.

Rider technique. The best riders synchronize their movements precisely with their horses' movements, whereas less-experienced riders are a little out of sync with the horse. The data we gather using the inertial sensors will clarify how the rider's pelvis moves in relation to the horse's back in each gait. Movements of the rider's trunk relative to the pelvis also provide useful information about whether the rider is leaning to the side or collapsing a hip, both of which transmit asymmetrical forces to the horse's back.

Support Our Research

It is very difficult to raise money for studies of healthy sport horses. To date, the research I've described in this article has been funded personally by the researchers. For information about making a donation toward these studies, please contact me at claytonh@msu.edu.

Meet the Researchers

Hilary Clayton, BVMS, PhD, Dipl ACVSMR, FRCVS, is professor and McPhail Dressage Chair Emerita at Michigan State University. She has been studying the performance of dressage horses and riders for over 30 years. A longtime contributing editor to USDF publications, she has been sharing her research findings with the USDF membership since the late 1990s.

Sarah Jane Hobbs, BEng, PhD, is a reader in equine and human biomechanics at the University of Central Lancashire in Great Britain. She has been collaborating with Hilary Clayton for over 10 years on studies of balance and self-carriage in dressage horses. She is the lead investigator for the Research and Consultancy in Equine Surfaces (RACES) team that evaluates equestrian surfaces. She was one of the scientists who ensured a safe arena surface for the 2012 London Olympics, and she subsequently spearheaded the writing of the FEI Equine Surfaces White Paper.

Filipe Serra Bragança, DVM, graduated from the Veterinary University of Lisbon in Portugal. His research involves the development and clinical implementation of techniques for objective equine gait analysis and lameness assessment. One aspect of this work is the development of the sensor-based EquiMoves system.

Marie Rhodin, DVM, PhD, Dipl ACVSMR, is a lameness clinician at the Swedish University of Agricultural Sciences. Her main research focus is the use of objective gait-analysis techniques to study horse-rider interaction, orthopedics, and interpretations of motion asymmetries in horses.

Elin Hernlund, DVM, PhD, is an equine clinician, researcher, and teacher at the University Animal Hospital and the Swedish University of Agricultural Sciences. One of her main research goals is to increase the complexity and specificity of objective lameness techniques and to introduce artificial intelligence in equine orthopedic diagnostic procedures.

Rosalie Bos, a former medal-winning dressage junior and young rider, is a final-year veterinary student at Utrecht University in the Netherlands. She intends to focus on the biomechanics, diagnostics, therapeutics, and rehabilitation techniques of sport horses.

Also involved in the study but not present for the data collection are Professor Mick Peterson of the University of Kentucky, and Professor Agneta Egenvall and Dr. Anna Byström of the Swedish University of Agricultural Sciences.