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Equine gait analysis: The slow start, the recent breakthroughs and the sky as the limit?

The horse is one of the very few animals that was not domesticated to produce tangible products like milk, meat or fur, but because of the great performance of its locomotor system ultimately leading to its current role as a sport and leisure animal. It may therefore not be surprising that over time there has always been great interest in the equine locomotor system, be it in a physiological sense (e.g. footfall patterns in different gaits) or in pathological cases where locomotion is impaired (lameness).

The ancient Egyptians asked the question whether or not at trot there was some moment in the stride cycle when horses had all four feet off the ground (Plato, cited by Muybridge 1899) [1]. Anybody working with horses now will know the answer, but even to this day nobody has seen the airborne phase in trot, as it is too short to be seen with the human eye. The definitive answer to this question was achieved in the 1870s when railroad magnate and horse owner Leland Stanford hired photographic pioneer Eadweard Muybridge, who provided for the first time ever pictures of the airborne phase at trot [1]. This successful endeavour was incited by the same spirit of curiosity as that of the ancient Egyptians, was justified by the great relevance of the horse for society and was facilitated by revolutionary high-tech developments, in this instance the introduction of photography.

We have now reached a stage in which technical developments have permitted the introduction of user-friendly quantitative gait analysis techniques in clinical practice. Accuracy and reliability of these techniques have increased to improve our performance in the assessment and monitoring of equine locomotor performance. However, these developments also urge us to reconsider our position as clinicians and pose new challenges in terms of interpretation of the data that are generated.

This editorial offers a concise historic overview of how we came this far, discusses the current status in the field and offers a perspective on future developments.

The early history of studies into equine gait

The ancient Greek philosopher, historian and soldier Xenophon (430-354 BC) is generally seen as the first major writer on equestrian issues [2]. Xenophon recognised the role of the hind quarters as the ‘engine of equine locomotion’, but it is Aristotle (384-322 BC) who first gives specific attention to the principles of quadrupedal locomotion (without specific focus on the horse) [3]. William Cavendysh, first Duke of Newcastle, studied equine gait with help of the sounds that the hooves make when they strike the ground [4] and in 1779 the first modern work that focuses entirely on equine gait was published [5] to help artists depict their horses in a more natural way and introducing new ways of depicting gait, like stick diagrams.

The first breakthrough: the introduction of photography and cine film

The 19th century saw many technological developments The French physiologist Etienne Marey developed ingenious mechanical devices to study equine gait and experimented, like Muybridge, with photography, inventing a ‘photographic gun’ that was able to realise serial photography, a forerunner of cine film [6]. Early last century, this medium was used extensively by eminent German scientists, to document equine gait and produce the first studies on the always difficult motion of the back [7,8].

The second breakthrough: computer-assisted gait quantification

In the last part of the 20th century, starting with high-speed film [9], various new techniques were developed greatly facilitated by the exponential growth of computer calculating power. The techniques allowed the quantification of both the equine gait kinematics (the description of the motion itself) and of the kinetics (the forces generated by locomotion). Publications in the field boomed [10], and insight in physiological and pathological (lameness) aspects of equine gait deepened rapidly. However, due to technical and economical constraints, the discipline remained largely lab-bound with no direct impact on clinical practice.

Quantitative gait analysis in a clinical setting

The Lameness Locator®[a] was the first tool generating quantitative data on locomotion that could be used in a clinical setting. The device gained widespread clinical acceptance and is currently still market leader in the field. The accelerometer-based device measures a couple of symmetry parameters in the sagittal plane at primarily the poll and the croup, which are used to provide information on left-right asymmetries during various phases of the stride cycle and hence on the presence and absence of lameness. This concept of body-mounted sensors has been developed further into more advanced inertial measurement units (IMUs) that often contain additional tools like a gyrometer, a magnetometer and often also a GPS device. The technique is currently one of the most used approaches for (almost) real-time measurement of equine gait. The main alternative approach is using so-called optical motion capture (MoCap) technology in which cameras record the 3D-position of markers on the horse’s skin overlying bony landmarks. The latter technique, of which the QHorse®[b] system is a good example that is used clinically in various large equine clinics, is generally more accurate and less prone to errors because of drift than the IMU-based systems. However, hardware for MoCap systems is more expensive and they are less versatile than the sensor technology because of the need for measurement in a dedicated calibrated space [11].

Clinical quantitative gait analysis: a fancy tool or a game changer?

The increasingly widespread introduction of quantitative gait analysis in clinical practice has shown that clients generally see the merit and are willing to pay for it, making the systems commercially viable. But what is the impact on the quality of clinical performance? The technical performance in terms of spatial and temporal resolution is much better than the human eye; all validated systems have a much lower limit of detection for asymmetry than the 25% reported for observation by the naked eye [12]. This much greater resolution has already led to a vehement discussion on whether the use of the term lameness, or better perhaps the interpretation of observed asymmetry, should be revisited [13,14]. It has also necessitated new research into the quantification of normal biological variation, both interindividual and intraindividual and both instantaneous and over time [15].

Intra- and interobserver agreement within and between clinicians on the assessment of equine gait is often low to very low [16]. Level of experience has an influence here, but even between experienced clinicians asked to only give a verdict of ‘fit or unfit to compete’ agreement was disappointing [17]. Use of quantitative gait analysis obviously increases repeatability, but this does not answer the -rather silly because too simplistic- ‘man versus machine’ question. In fact, the answer to this question is that the skilled clinician will always remain necessary to interpret data in terms of discomfort of the horse and give a final clinical verdict in a given case [18]. But the quantitative systems are certainly highly valuable tools for clinical practice. In the words of emeritus Professor Derek Knottenbelt: ‘Technology won’t replace vets… but vets who use technology logically and carefully will replace those who don’t’ [19]. So, yes, quantitative gait analysis can be considered a game changer.

The future

The advances in both sensor technology and optical motion capture systems are largely driven by developments in very powerful high-investment sectors alien to the equine sector, like the aerospace and animation industries. These advances make the hardware more performant and more affordable. The current gait analysis systems are largely limited to measuring symmetry parameters in the sagittal plane or at the *tubera coxae*, but a logical next step is expansion to other parts of the body, including the (distal) limb, enabling a more comprehensive assessment of gait [20]. While the specifications of the hardware in terms of precision and accuracy will continue to improve, functional validation of the new devices will continue to be needed, that is, determining both the normal ranges of new gait analysis parameters and the relevance for clinical use for assessment or prediction of performance.

Ever-increasing computational power, in which gigantic investments are made at present, has led to artificial intelligence, deep learning techniques, and 'big data' databases. Machine perception and machine learning is currently being used in humans to understand and interact with dynamic real-world scenes, aiming at improving healthcare and safety, as well as for human pose estimation and as an aid to referees in human sport events. In the area of optical motion capture, marker-less systems and artificial intelligence are the likely future avenues for machine learning techniques in human [21,22]. These technologies are currently being tested by one of the authors (C.G.A.) for automated animal welfare monitoring, including musculoskeletal health and disease (mainly lameness). It can be expected that the introduction of analysis techniques based on big data will revolutionise the interpretation of gait data in the not too distant future.

Equine gait analysis has been of interest ever since horses were domesticated. After a slow start, quantitative gait analysis techniques have now made it to the clinic. They are here to stay and will revolutionise equine clinical orthopaedics, just as the introduction of diagnostic imaging has, and will continue to inform the discipline. Equine clinical orthopaedics without imaging is unthinkable at present and so will it be for quantitative gait analysis in a not too distant future. Gait analysis techniques will not replace the clinician and optimal use of both imaging and gait analysis techniques requires sound clinical judgment. Interpretation of the results should be done with wisdom, but gait analysis tools will certainly bring evidence-based veterinary medicine to a higher level.

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