Equine Veterinary Journal

Equine Veterinary Journal ISSN 0425-1644
DOI: 10.1111/evj.13162

Practical uses of quantitative gait analysis in horses

When we hear 'gait analysis' we immediately think 'lameness'. This is not surprising because these technologies are used to measure values that relate to lameness, in both clinical and experimental set-ups. However, there are many other practical uses of equine quantitative gait that can be used in clinics and training centres with the goal of improving equine health and performance. Some may require more, and others less, advanced equipment and expertise, but all current technologies are aiming to become more user-friendly for the equine practitioner.

Quantitative gait analysis can identify and measure potential gait disturbances in horses with musculoskeletal or neurological conditions. Its use in aiding lameness diagnosis and monitoring is mainly based on measuring gait asymmetries, determining whether those asymmetries are over pre-set thresholds and deciding on their clinical relevance. Much work has already been done to investigate symmetry and asymmetry values of the motion of various body parts (including vertical displacement of head, withers and pelvis; joint angle parameters of the limbs and vertebral column), stride parameters and limb loading; as well as the symmetry values seen under different conditions such as different disciplines, training, type of terrain, with or without a rider and during lungeing or when moving over a straight line [1–7]. Further refinement of knowledge on gait parameters is still warranted, and research in the area will not cease as technologies evolve.

Although perfectly suited for the purpose, quantitative gait analysis has been used in very few studies of neurological conditions. Gait parameters relevant to ataxia have been successfully measured in an experimental study [8]. In a kinematic study with clinically ataxic and non-ataxic horses, Olsen *et al*. [9] showed that motion capture equipment can objectively aid the assessment of horses with ataxia. These studies show that this type of analysis has the potential to aid diagnosis in neurological cases and monitor the impact of their treatment.

Quantitative gait analysis can be applied in the evaluation of training and exercise programmes, and sport-specific biomechanics. Investigating the biomechanical horse-rider interaction in international endurance competition, two accelerometers recorded the vertical displacements of horse and rider to analyse riding techniques during different gaits in elite and advanced horse-rider dyads. Advanced duos maintained a more stable speed and elite duos increased the use of the sitting canter, while both groups used 2-point trot less often than other strategies. The study highlights the great potential of accelerometer-based wearables to characterise gait and riding strategies [1]. Using also accelerometer-based devices, Heim *et al*. [2] established the normal values for latero-medial and dorso-ventral range of motion (ROM) of the vertebral column in 27 Franches-Montagnes stallions and compared it with a group of mix-bred horses trotting under different exercising conditions. Variability was lower in the Franches-Montagnes stallions, suggesting that vertebral ROM values are characteristic for a particular breed. Trotting under saddle significantly reduced the ROM, with sitting trot resulting in a significantly lower ROM than rising trot [2]. This approach could be used to further determine normal values of vertebral ROM in other breeds, thus aiding in monitoring the effects of exercise and training, and helping with the diagnosis of back disorders.

Limb kinematics was studied using high speed motion capture in twenty clinically sound horses in active dressage training. Horses were divided into young and mature groups and were trained on two different surfaces while performing collected vs. medium/extended trot. Stride parameters and flexion-extension angles were analysed in all limbs. Medium/extended trot increased extension of the fore- and hindlimb fetlock joints compared with collected trot in both young and mature dressage horses, respectively [5]. Kinematic characterisation of lengthened and collected paces may hold the key to better understanding of optimal dressage training and competition which in turn may lead to improved performance and lower injury rates in all equestrian disciplines.

Accelerometers are also very useful to quantify locomotor activity: In a study by Fries *et al*. [10], activity count and step count were recorded in six horses performing different controlled activities including grazing, walking at different speeds, trotting and cantering using devices at different locations on the body. Most of the locations resulted in measurements that accurately quantified all or some of the locomotor activities at different speeds and gaits, particularly when positioning the device on the hindlimb, and on the head to differentiate grazing from standing. The ability to quantify different behavioural activities has great potential for investigating behavioural problems, investigating welfare issues, and facilitating training and rehabilitation programmes following injury.

A further avenue for practical quantitative gait analysis lies in easily applicable clinical methodologies for the investigation of linear and temporal stride characteristics and estimation of forces interacting with the horse's body. Values generated from sound individuals can serve as a baseline to compare with clinical cases. A study by Holt *et al*. [11] proposed a simple kinematic method using force plates for detecting hoof-on, hoof-off, and peak ground reaction forces at walk, trot, and canter with acceptable accuracy. Another study evaluated stride detection using inertial measurement units (IMUs) [12]. Analysing these parameters in sound horses can be useful for investigating competition surfaces, training regimens and horse tack, and has potential for clinical applications in pathologies affecting gait.

Equine biomechanics research is increasingly aimed at refining analyses and hardware to achieve more accurate and practical results. Requiring a more special type of equipment, biplane high-speed fluoroscopy, autoscoping and scientific rotoscoping, were validated for measuring the motion of the distal limb during simulation of landing, stance phase and lift-off in an ex vivo model. These techniques were shown to be very promising non-invasive motion capture options [13]. Recently, Serra Bragança *et al*. [14] quantified the effect of misplacement of markers or motion-sensors for gait analysis quantification, showing that in hindlimb lameness, marker misplacement significantly affects the calculated symmetry parameters of the pelvis. Errors like this can be misleading in cases of mild lameness. Using IMUs in training Thoroughbreds for early detection of injuries, repeatability was lower than previously reported [15]. Together these studies illustrate the importance of ongoing investigation of both traditional and novel equine biomechanical techniques.

In conclusion, equine quantitative gait analysis is not limited to lameness investigation; there are emerging practical uses in neurology, optimising training, riding and competition programmes. Further, baseline values in healthy individuals have been established for some but not all breeds and sports. There is an ongoing quest for more accurate, more performant, more practical and more user-friendly devices. Today, objective, quantitative gait analysis in the horse has outgrown the laboratory and is infiltrating all horse-related activities.

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