Decision Making: Numbers versus Evidence

by Dr.-Ing. Thilo Pfau, Co-Owner and Technical Director of EquiGait Ltd

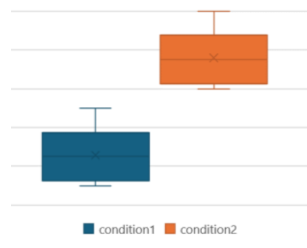
Here we address the following questions:

- What is the difference between a ‘number’ and ‘evidence’ when making decisions about specific aspects of locomotion?

How much ‘trust’ can we put in numerical measurements?

There are an ever-increasing number of ‘devices’ and ‘apps’ allowing for the measurement of a variety of ‘parameters’ with more or less relevance for measuring movement or performance. A brilliant example is the number of fitness apps for humans! All provide numerical outputs for things such as distance covered, average, minimum/maximum speed, number of steps, calorific consumption and many more. It is very easy to take these numerical outputs at ‘face value’ and accept them “as is” without considering how they have been measured or estimated. That however is crucial for turning numerical decision making into evidence-based decision making.

Box plot showing numerical values of two different conditions

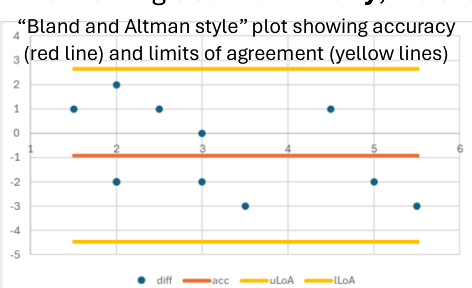


For example, based on the technology used (e.g. GPS, inertial sensors, video), the placement of the measurement device (in your pocket, on your wrist, on your arm, on your shoe etc) and the conditions under which the measurements have been taken (indoor/outdoor, treadmill/over ground, woodland/city/open area etc), different technological solutions for measuring ‘fitness’ parameters are more or less accurate and precise.

Accuracy and precision

When talking about **accuracy**, we are concerned with how well the measured parameter matches the true value **on average** (see red line in figure to left), when we talk about **precision**, we consider **how much variation** there is across multiple measurements with respect to the difference between the measurement value and the true value (see region between the two yellow lines in figure). Now, when it comes to movement in horses, there is a whole host of parameters that influence the size of the measured parameters: we have discussed the influence of speed in a previous leaflet and the ‘robustness’ of movement symmetry against variations in speed. Despite this robustness, we need to consider how confident we are in movement symmetry parameters.

“Bland and Altman style” plot showing accuracy (red line) and limits of agreement (yellow lines)

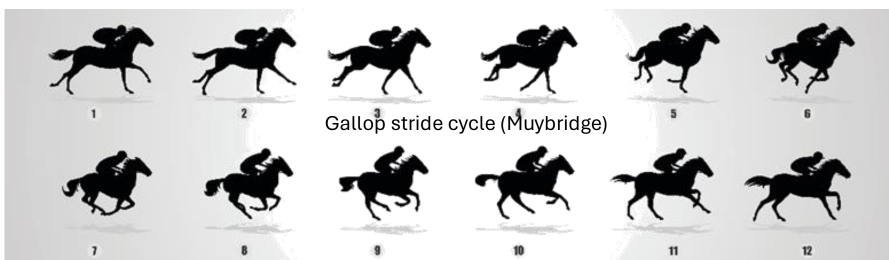


When does a numerical difference represent a true change: ‘evidence’ versus ‘just numbers’?

Imagine you are measuring head, withers and pelvic movement symmetry with one of our EquiGait systems. You notice that parameters are different in value compared to the last time you had measured that particular horse. Is this numerical difference truly evidence of a change in the 'biology', i.e. is this horse 'performing' differently today? There are some considerations that spring to mind immediately that will help us provide an answer to this question.

The importance of stride-to-stride variability.

What makes quantification of a moving horse (or other animal) different from many other measurements, is that we are taking 'dynamic measurements' from a moving body. Now luckily for us, 'gait' is characterized by its repetitive nature. Hence, we can quantify the 'same parameter' over and over again, typically one measurement per cycle, i.e. we measure the same thing for every step or stride that the horse takes. However, this also means that there are variables that influence our measurement. Things like speed (we have discussed this earlier), surface type and preparation, surface grade (level/uphill/downhill), exercise direction (straight, circle), presence of tack and/or rider, fatigue and many more can be named. It is a lot harder to standardize all these factors compared to, for example, taking a radiograph in a standing horse. For the latter, the horse is typically presented in a standardized setting, such as a hospital where the environment has been optimized for exactly that measurement. This is not the case when taking measurements of a moving horse: we specifically want to do measurements that more closely reflect 'real-life' tasks. It may have been noted that the horse is showing 'reduced performance' under specific circumstances. If we wanted to make 'laboratory quality' measurements, we could have stuck to the multi-camera measurements that are possible with expensive 3D motion capture setups rather than measuring with accurate and precise, yet more affordable inertial sensors.



Gallop stride cycle (Muybridge)

Since we want to undertake 'real-life' measurements, we need to think about factors such as stride-to-stride variability. While with our mobile data collection methods, such as inertial sensors, we can that we can quantify the same parameter again and again and hence be confident in our results, there are 'environmental' variables that may influence the data quality or repeatability. True changes, such as a horse that gradually develops a performance limiting restriction, might get 'hidden' by 'unwanted' variability in the data. One important source of variability is the mere fact that the horse is not a robot repeating a task in an identical manner, but it is a biological system that reacts to external stimuli resulting variations from stride to stride.

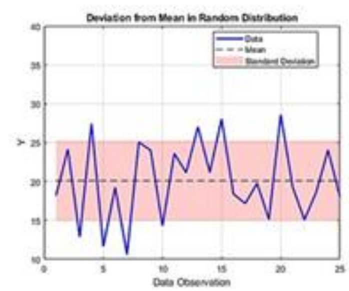
Consequences for decision-making with inertial sensor systems

In the context of inertial sensor-based gait analysis, we benefit from the fact, that inertial sensor-based measurements have been used extensively for years. We know that the measured parameters are accurate and precise[1,2], that they closely associated with the underlying force production [3,4] and that they are even comparable between different inertial sensor-based systems[5]. Add to this convincing quantitative information about the variability of functionally relevant measurements[6], it is clear that inertial sensor-based systems provide practically useful information allowing us to distinguish between 'real changes' (i.e. changes that are functionally relevant) and changes that are within the 'expected range of repeat measurements'. Based on our method comparison study[5] together with the published 6 mm and 3 mm repeatability values for head and pelvic movement symmetry[6], we can confidently state the following:

- head movement symmetry of 8 mm or less and pelvic movement symmetry of 4 mm or less measured with EquiGait systems should not be seen as an automatic sign of 'abnormal' movement during straight-line trot.
- when looking for evidence of a 'true' change, for example in association with treatment or rehabilitation or after a diagnostic intervention, movement symmetry changes need to exceed these values during straight-line trot.

The importance of establishing repeatable baseline values:

It is important to keep in mind, that these guideline values apply to a specific technology and to very specific conditions: straight-line trot, with the horse led in-hand, on hard, even ground. But even then, common sense needs to be applied: when a horse behaves in an 'excited' or 'fractious' manner, tossing its head, spooking in the presence of external stimuli or in an unfamiliar environment, speeding up, slowing down, changing gait etc, this will naturally increase its stride-to-stride variability and reduce our confidence in the measurements.



https://en.wikipedia.org/wiki/Deviation_%28statistics

While it is possible to measure such movement, the quantitative output may not provide the desired insights: the saying "garbage in, garbage out" springs to mind. Care should then be taken when for example aiming to quantify the effect of an 'intervention', such as a diagnostic block in a veterinary lameness examination: attempts should be made to quantify movement patterns from multiple runs until it is clear, that the results are consistent. Only then should they be used as baseline for further comparison.

Of course, a lameness examination consists of more than just straight-line, in-hand trot. However, this is beyond the topic of this current leaflet. It does not mean that other exercise conditions such as circular movement on the lunge and on different surfaces or assessment under the rider are any less important and conveniently EquiGait systems are designed to measure more than just straight-line trot!

The special importance of upper body movement symmetry

We need to briefly revisit the influence of speed for biomechanical assessments. We have outlined, that upper body movement symmetry is comparatively robust against changes in speed. There is, however, another reason why upper body movement is well suited for providing more repeatable and functionally relevant measurements compared to more detailed measurements of specific limb movement parameters. Parameters such as landing time, mid stance time, breakover time or joint angles during the support or flight phase are often mentioned when discussing horse movement.

To appreciate the 'special importance' of upper body movement, it is really important to understand, that horse limbs can be mechanically modelled as 'damped springs'[7]. The fetlock joint acts in a manner that allows it to provide a linear relationship between the fetlock angle and the maximum force produced by a limb[8]. It is also instrumental for reducing vibrations that occur when a hoof contacts the ground[9]. So how does this relate to upper body movement? The mostly passive, elastic, spring-like behaviour of each limb[8] allows the horse to effectively "smooth out" inconsistencies encountered during locomotion making use of the limbs' damping properties[7]. Think about how horses can navigate uneven terrain without any notable coordination issues. Not a

trivial task for an animal with 500 kg body mass. While at each foot contact, the height or gradient of the surface (think bumps in a turf surface) as well as its hardness or traction properties (think more or less heavily used areas of a riding arena) create a different 'environment' for each step, the horse's upper body will continue to move at a steady, repeatable gait pattern. The environmental inconsistencies dictate how the horse's hooves impact the ground, how they penetrate the surface and how the horse pushes off from the ground. While this leads to a high degree of stride-to-stride variability for example on soft ground for example for limb timing parameters[10], there are only minimal differences in movement symmetry and back movement obvious between different surfaces[11,12].

Take home messages:

- Evidence-based decisions about changes in locomotor 'performance' require consideration of the stride-to-stride variability: **"evidence" not just "numbers".**
- **Robust stride-to-stride variability estimates** are available for upper body movement:
  - from **practically relevant conditions** and with **inertial sensor** measurement.
  - in **substantial numbers of horses**.
  - have led to **robust guideline values** for variation of and changes in movement symmetry.
- The spring-like behaviour of horse limbs 'filters out' inconsistencies between strides:
  - this results in **consistent upper body movement** – movement symmetry and back movement – with reduced variation compared to hoof and limb-based measurements.
  - this provides **maximum confidence** in quantitative, functionally relevant measurements and is essential for **evidence-based decision-making** in the context of locomotor performance.

Conclusion:

EquiGait inertial sensor gait analysis is providing **reliable, accurate and precise** measurements providing quantitative insights into **functionally relevant movement** parameters for aiding **evidence-based decision** making based on **scientifically proven methods and principles**.

Our systems go **beyond 'numerically replicating' visual assessment**: **withers** movement symmetry is crucial for differentiating between **primary and compensatory head movement** adaptations and six degree of freedom **quantification of "back movement"** is aiding decision making in **horses with poor performance**.

Our advice: Carefully **check out validation studies** before investing in gait analysis equipment!

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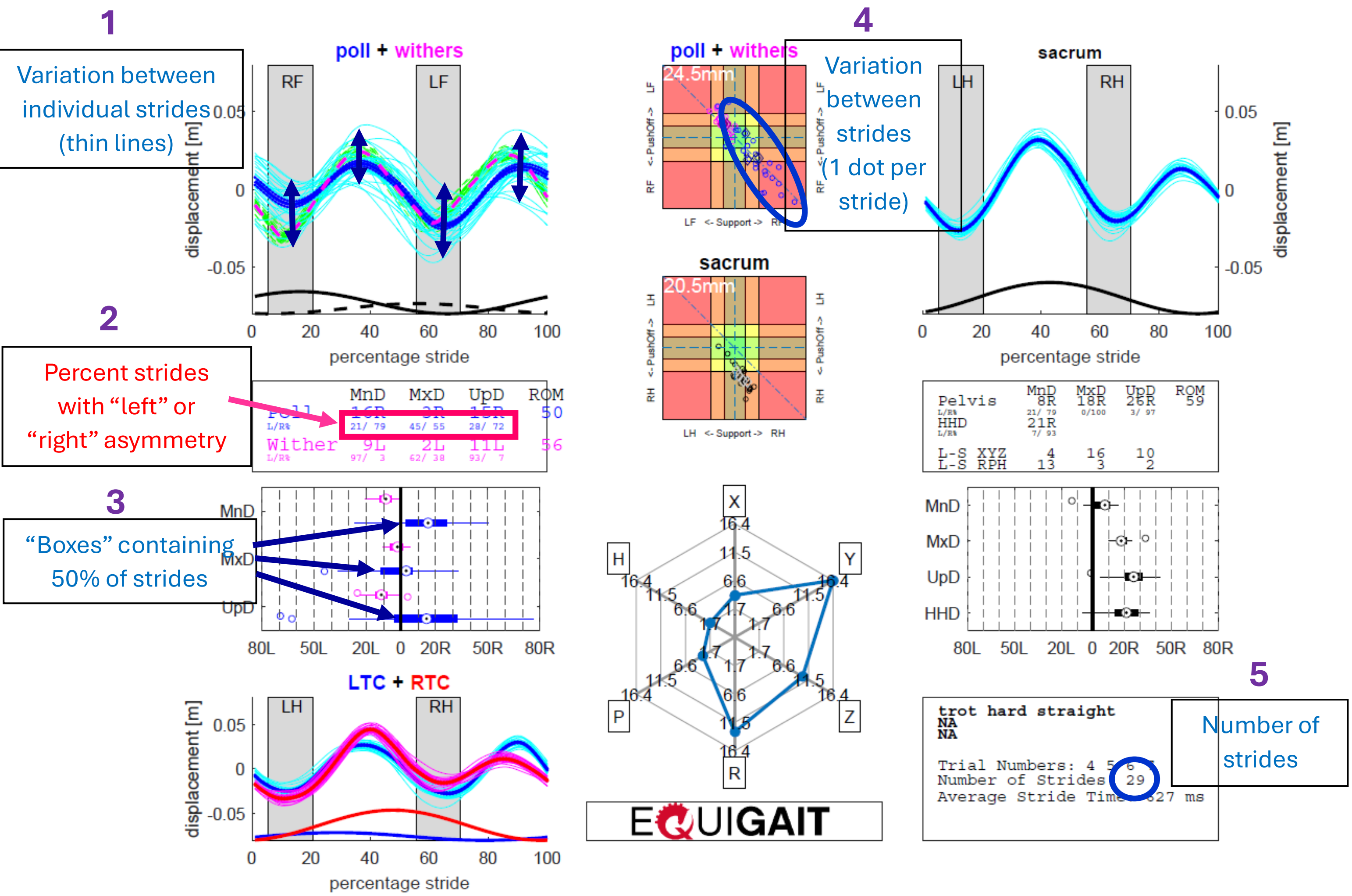

A typical **EquiGait** output of our **6-sensor** movement symmetry system: the system measures **head, withers, sacrum and left and right tuber coxae movement symmetry**. It also quantifies **lumbo-sacral range of motion** with 6 degrees of freedom.

Here we highlight how our system provides **visual and numerical** insights into the **variability** of the analyzed data:

1. Individual vertical **movement traces** over multiple stride cycles
2. **Percentage strides** to exhibit left or right-sided asymmetry for weight bearing (MnD) and pushoff (MxD, UpD)
3. **Box and whisker plots** for ease of visualizing whether or not ‘symmetrical movement’ (value of 0) is included in the interquartile range of the collected data
4. Visualization of weight bearing and pushoff asymmetry in a **‘target plot’**. With each stride symbolized by an individual ‘dot’ it is easy to appreciate how much variation there is between strides
5. The **number of strides** analyzed

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