# Accuracy and Precision of EquiGait Gait Analysis Systems

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

On your quest for a gait analysis device for your business, you will undoubtedly have come across a whole range of options.
How do you decide? In our opinion, there are a few important considerations:

**Accuracy and precision: what are they?**

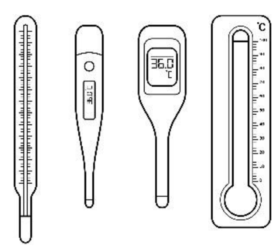
Let's use the example of quantifying movement symmetry, which most prominently features as an important characteristic for aiding decision making in veterinary lameness examinations. **Accuracy** describes the **average difference** between a number of measurements and their true value, while **precision** quantifies the **amount of variability between these measurements and their true values**. Thinking in terms of darts and the task of hitting a bullseye: the 'true value' is the position of the bullseye, the measurements is the position of the arrow. Imagine you are throwing a number (>1) arrows, the accuracy is the average value of the distances between each arrow and the bullseye. The precision is the standard deviation of these distances.

In terms of gait analysis, the 'true value' is a little harder to come by. Typically, we consider the measurements of a reference system as that true value. Oftentimes this reference system is a 3D motion capture system. a system that measures the position of objects, often specific markers placed on an object, using a number (≥2) of video cameras mounted at known locations. These expensive systems are known to deliver sub-millimeter accuracy.

The measurement value is the 'equivalent' value as provided by the gait analysis system under evaluation, for example a movement symmetry value. As a concrete example, multiple scientific studies have been performed, quantifying head and pelvic movement symmetry in trotting horses and comparing the outcome value of a novel system (the system that is to be evaluated for example an our EquiGait inertial sensor systems or a markerless video system) to a reference system (3D motion capture)[1–3].

**Accuracy or precision: Which one is more important?**

Generally, **precision is what matters**!
Imagine, you have designed a novel thermometer and want to show that people can trust the measurements of your new device – this is a classic example utilized in one of the most heavily cited scientific method comparison studies laying the groundwork for how to compare two methods[4].
What if your novel device consistently, i.e. in every single measurement you undertake, delivers a value that is 5 degrees higher than the actual true value? No reason to worry, you can



correct your measurement by simply subtracting 5 degrees from the displayed measurement. In that case, the accuracy of your device is not particularly high, but your precision is excellent since you know that your novel device always measures 5 degrees more than the true value. After correcting for the constant difference, you have a a device with high precision and accuracy.
What about the case when your novel device provides an average difference of 0 degrees (excellent accuracy), yet individual differences vary between 5 degrees lower and 5 degrees higher than the true value? Now, if you use your device to measure a value of 20 degrees and you have not used your reference device at the same time, you have little idea about what the actual values is: it could be 15 degrees (5 less than displayed), it could be 25 degrees (5 more than displayed) or any value in between. Based on your method comparison study, you simply can not be sure all you can say that with 95% confidence you have measured a temperature between 15 and 25 degrees. Your developed device is delivering high accuracy (the average difference was 0 degrees) but has low precision (there is high variation between repeat measurements). It is much harder to make corrections to the measurements of an imprecise device, unless you have indeed identified specific underlying causes for the imprecision.

**Accuracy and precision: considerations for gait analysis.**

Now, when it comes to gait analysis, it gets a little more complicated. The 'true value' is not a static value, i.e. not a constant, but it is changing with time. When conducting gait analysis, the horse is after all typically moving not. One commonly used gait analysis outcome parameter is movement symmetry: the aim is to quantify how much difference there is in the position of the head (or pelvis) between the two halves of a stride cycle. Essentially, imagine your dartboard is moving in space when you are throwing your dart! What this means, that the true value we have to compare each of our measurements to, is changing. But by how much? Luckily, we have some crucial knowledge about the underlying characteristics of the process – i.e. how horses move. For example stride to stride variability of movement symmetry of a trotting horse is in the area of 3 to 5 mm for pelvic movement and slightly more (7 to 11 mm) for head movement[5]. A more precise system will provide a better reflection of this stride-to-stride variability, i.e. it will be able to follow changes between stride cycles more closely, and hence it will provide a better representation of the underlying biological variation. Consequently, this will result in a higher chance of detecting changes in the underlying process: the more closely your measurements follow the horse's movement, i.e. the smaller the uncertainty that is introduced by the measurement, the more likely that small changes between 'interventions' (after diagnostic analgesia, after change in shoeing, with treatment) can be detected.

What is precise enough? It would certainly appear desirable to have a measurement with a precision (or even better with limits of agreement[4] compared to true values) that is below said stride-to-stride variability. Based on published values this would be around 5 mm for pelvic movement symmetry and around 10 mm for head movement symmetry[5]. Other values that are of importance here are for example relating to the day-to-day or within-day variability of gait measurements. If you want to provide useful information about any changes in relation to your interventions – such as diagnostic blocks during a lameness exam or after shoeing – or in association with your treatment or rehabilitation regimens, then your measurements need to be able to capture these within- or between-day variations. Relevant scientific studies indicate that daily and weekly differences in movement symmetry impose similar boundaries on the required precision[6,7].

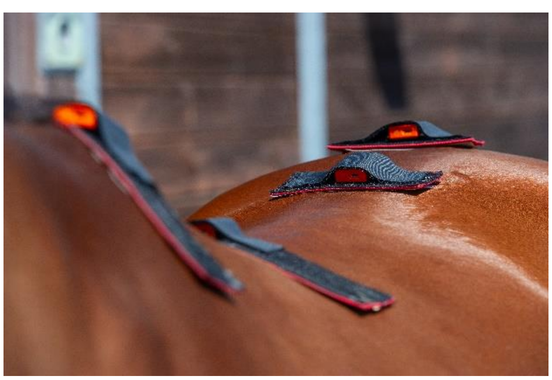
**Precision of EquiGait systems:**

Validation studies, the results of which have been published in peer-reviewed scientific Journals indicate that limits of agreement of our EquiGait systems in comparison to 3D motion capture are in this targeted area of around +/-5 mm[1,2].

Comparing two inertial sensor-based systems to each other, limits of agreement of between 3 to 5 mm for pelvic movement and of 7 to 9 mm for head movement confirm these assessments[8]. It however appears to be noteworthy, that direct comparisons are sometimes rendered difficult due to normalization procedures employed aiming at creating values that are universally applicable across horses of different disciplines. Our **EquiGait systems measure 'real life' values in millimeters** that do not require any further calculations or normalizations.

Finally, you may ask: what about video-based assessments? A comparison study between markerless video and 3D motion capture[3] has found very similar limits of agreement between the two optical methods (+/-5 to 6 mm) and slightly wider limits of agreement between our EquiGait system and the same markerless video system when used in Quarter horses[9]. So, in essence, when the aim is to measure vertical head and pelvic movement symmetry, inertial sensors and video-based systems agree sufficiently. When a colleague provides you with values from a different gait analysis system, the results are likely in the same ball park as what you would have measured with your EquiGait system. **Of course, our EquiGait systems measure a lot more than vertical movement of head and pelvis!** We are champions in quantifying **compensatory movement patterns** as well as in assessing **complex back movements** with relevance for horses with back problems or poor performance syndrome.

**Conclusion:**



**Precision**, the amount of variability between measurements and their true value is **more important than accuracy**. Accuracy can be easily corrected for, once determined. Precision introduces uncertainty that needs to be taken into account when basing decisions on quantitative measures.

Since gait analysis is conducted in moving horses, **precision** of gait analysis systems should be **good enough to capture stride-to-stride variability and**

**differences between consecutive measurements** conducted for example as part of a lameness examination or over the course of a treatment of rehabilitation regimen.

**EquiGait gait analysis systems** meet and exceed this challenge:

we provide **state-of-the-art, precise sensor-based quantification** of:

- head, withers and pelvic movement for quantifying **primary and compensatory movement deficits.**
- thoraco-lumbo-sacral (aka 'back') movement with 6 degrees of freedom for describing **complex movement patterns** in horses with suspected **back problems or poor performance syndrome.**

## List of References


1. Pfau, T., Witte, T. H. & Wilson, A. M. A method for deriving displacement data during cyclical movement using an inertial sensor. *The Journal of experimental biology* **208**, 2503–2514 (2005).
2. Warner, S. M., Koch, T. O. & Pfau, T. Inertial sensors for assessment of back movement in horses during locomotion over ground. *Equine Veterinary Journal* **42 Suppl 3**, 417–424 (2010).
3. Lawin, F. J. *et al.* Is Markerless More or Less? Comparing a Smartphone Computer Vision Method for Equine Lameness Assessment to Multi-Camera Motion Capture. *Animals* **13**, 390 (2023).
4. Bland, J. M. & Altman, D. G. Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet* **1**, 307–10 (1986).
5. Keegan, K. G. *et al.* Assessment of repeatability of a wireless inertial sensor-based lameness evaluation system for horses. *American Journal of Veterinary Research* **72**, 1156–1163 (2011).
6. Sepulveda Caviedes, M. F., Forbes, B. S. & Pfau, T. Repeatability of gait analysis measurements in Thoroughbreds in training. *Equine Veterinary Journal* **50**, 513–518 (2018).
7. Hardeman, A. M., Serra Bragança, F. M., Swagemakers, J. H., Weeren, P. R. & Roepstorff, L. Variation in gait parameters used for objective lameness assessment in sound horses at the trot on the straight line and the lunge. *Equine Vet J* **51**, 831–839 (2019).
8. Pfau, T., Boultbee, H., Davis, H., Walker, A. & Rhodin, M. Agreement between two inertial sensor gait analysis systems for lameness examinations in horses. *Equine Veterinary Education* **28**, 203–208 (2016).
9. Pfau, T. *et al.* Comparing Inertial Measurement Units to Markerless Video Analysis for Movement Symmetry in Quarter Horses. (2023).