Comparison of a novel instrumented hoof boot with two objective systems for equine gait analysis in lame horses

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Introduction

Objective gait analysis systems are increasingly used to complement subjective lameness evaluation [1]. In daily clinical practice data acquisition is mainly based on kinematic methods, analysing the position of the horses' body at specific timepoints. Inertial measurement units placed on defined anatomical landmarks or smartphone-based optical motion capture systems using artificial intelligence for markerless analysis are used [2]. However, acquisition of ground reaction forces, i.e. a kinetic approach is considered the gold standard for assessment of supporting limb lameness. A novel instrumented hoof boot is capable of measuring the hoof pressure on the ground independent of the location in real-time to determine gait asymmetries in horses [3].

Objective

The aim of this study was to determine correlation and agreement between kinetic data from a novel instrumented hoof boot (consteed – the smart horse sneaker™, ContiTech Deutschland) and two widely used kinematic systems using body mounted inertial measurement units (Equinosis Q Lameness Locator®, Equinosis) and optical motion capture (Sleip™, Sleip AI AB), respectively in naturally lame horses.

Materials and Methods

Inclusion criteria
- Horses referred for lameness examination
  - Aged ≥ 3 years
  - Lameness persistent > 2 weeks
  - Lameness visible only at trot (grade 1–2 / 5)

Instrumentation and data collection
- (1) Instrumentation with consteed – the smart horse sneaker™ **(CS)** and
- (2) Equinosis Q Lameness Locator® **(LL)** according to the manufacturer's recommendations
- (3) Sleip™ **(SL)** data was collected with an IPhone15 Pro positioned on a tripod
- Simultaneous data collection with devices 1–3 **(Fig.1)**
- Horses were trotted four times 35 m in a straight line on hard ground

Fig. 1: Horse equipped with consteed – the smart horse sneaker™ and Equinosis Q Lameness Locator®

Data processing
- Mean values from two repeated measurements per system
- Left/right limb differences of indicated values

CS: Peak vertical force	Left–Right Symmetry Index front/hind
LL: Minimum head/pelvis position	HDmin/PDmin
SL: Minimum head/pelvis position	$MinDiff_{Head}/MinDiff_{Pelvis}$

- Separate analysis of front- and hindlimb lameness data

Statistical analyses
- Data analysis based on three different methods [2; 4; 5] using the statistical programming environment R (Version 4.5.1; R Core Team 2024)
- Kendall rank correlation coefficient
- Intraclass correlation coefficient (ICC) after z-standardisation
  - Two-way random-effects-model, absolute agreement (2,1)
  - Two-way mixed-effects-model, consistency (3,1)
- Bland-Altman analysis after z-standardisation
- Significance level was set at α=5% (two-sided)

Results

Study population and recorded data
- Twenty-six horses of different breeds, aged 11±5 years, different lameness diagnoses
- Total of 32 datasets (15 frontlimbs, 17 hindlimbs)
  - Higher variability in the lame limb axis compared to the non-lame limb axis was detected with **CS**, **LL** and **SL**
  - Details on data location and variability, median and interquartile ranges of lame horses are provided in **Fig. 2**
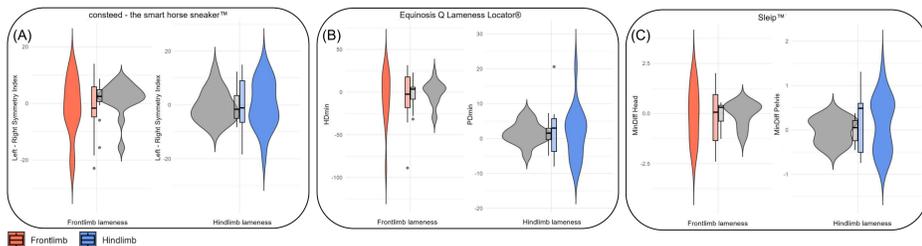

Fig. 2: Violin plots of front- and hindlimb lame horses, showing primary lame limb axis (colored) and non-lame limb axis (grey). Positive values indicate lameness in the right limb, negative values in the left limb. (A) consteed – the smart horse sneaker™ Left-Right Symmetry Index of front- and hindlimbs. (B) Equinosis Q Lameness Locator® HDmin of front- and HDmax of hindlimbs. (C) Sleip™ $MinDiff_{Head}$ of front- and $MinDiff_{Pelvis}$ of hindlimbs.

Kendall rank correlation coefficient
- Frontlimb lameness: strong positive correlations between measurements with all systems (**CS/LL** and **CS/SL:** r=0.733; **LL/SL:** r=0.886)
- Hindlimb lameness: moderate positive correlations between **CS/LL** (r=0.421) and strong positive correlations between **CS/SL** (r=0.647) and **LL/SL** (r=0.568)

Intraclass correlation coefficient
- Frontlimb lameness: very strong correlations between the systems (**CS/LL** ICC2: 0.898, ICC3: 0.891; **CS/SL** ICC2: 0.896, ICC3: 0.890; **LL/SL** ICC2: 0.920, ICC3: 0.915)
- Hindlimb lameness: strong to moderate correlations between systems (**CS/LL** ICC2: 0.546, ICC3: 0.531; **CS/SL** ICC2: 0.798, ICC3: 0.789; **LL/SL** ICC2: 0.798, ICC3: 0.788).

Bland-Altman analysis comparing agreement of used systems
- No systematic deviations between the systems in both, front- and hindlimb lame horses were shown **(Fig. 3)**
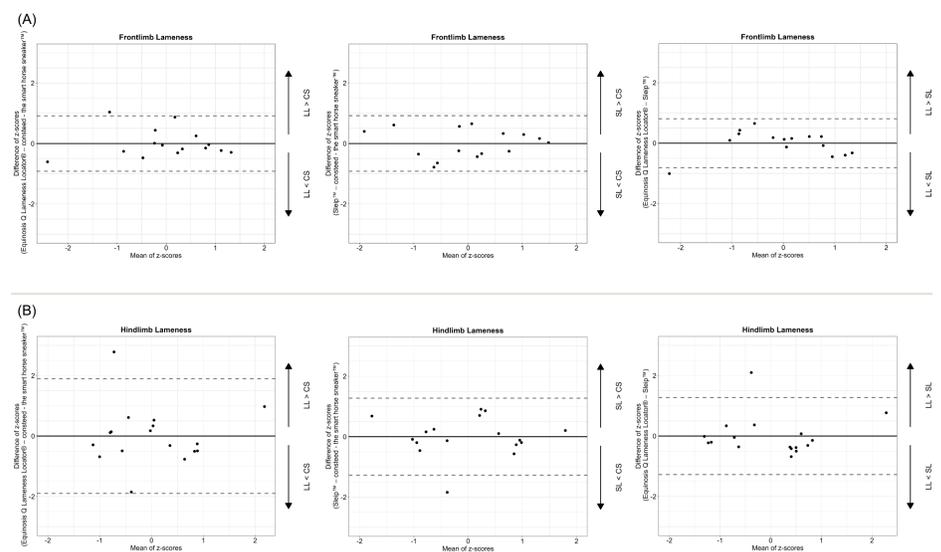

Fig. 3: Bland-Altman plots after z-standardisation. (A) In frontlimb lame horses, the 95% limits of agreement of Equinosis Q Lameness Locator® **(LL)** and consteed – the smart horse sneaker™**(CS)** were ±0.915, of **CS** and Sleip™ **(SL)** were ±0.92 and of **LL** and **SL** were ±0.809. (B) The kinetic and kinematic systems in hindlimb lameness showed a slightly weaker agreement with 95% limits of agreement between ±1.898 for **CS** and **LL** and ±1.275 for **CS** and **SL** as well as **LL** and **SL**.

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Discussion

Comparison between consteed – the smart horse sneaker™, Equinosis Q Lameness Locator® and Sleip™ showed overall strong positive correlations but a slightly lower agreement in horses with hindlimb lameness. Kinetic and kinematic systems detect different aspects of lameness – forces or movements – which might lead to a lower agreement between the systems. Furthermore, secondary lameness may have caused individual compensation strategies that are reflected differently by CS, LL and SL. It has to be considered that biomechanics differ between front- and hindlimbs.

Limitations of the study include a small number of horses, a mixed-breed population and different causes of lameness.

Conclusion

Consteed – the smart horse sneaker™, Equinosis Q Lameness Locator® and Sleip™ consistently detect gait asymmetries in the same direction in naturally lame horses at a trot on a straight line on hard surface.

Abbreviations
CS – consteed – the smart horse sneaker™; LL – Equinosis Q Lameness Locator®; SL – Sleip™, ICC – Intraclass correlation coefficient

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