Letters in Animal Biology

Letters in Animal Biology

Journal homepage: www.liabjournal.com

# Biomechanics of the locomotor system in sport horses: Diagnosis of disorders and injury prevention

Olena Martynova

*Department of Information Technologies, Odesa State Agrarian University, 65012, 13 Panteleimonivska Str., Odesa, Ukraine*

***Article info***

Received: 09 June 2026
Received in revised form: 12 August 2026
Accepted: 14 August 2026
Published online: 22 August 2026

**Keywords**

Horse
Kinematic parameters
Stride length
Equipment
Tarsal joint
Inertial sensors

* *Corresponding author:*
*Olena Martynova*
*Email:* *ol.martynova@ukr.net*

***Reviewed by:***

*Consent to publish the name of the reviewers could not be obtained*

**Abstract**

This study hypothesised that integrated assessment of kinematic, load-distribution, thermal, and inertial parameters could distinguish clinically healthy sport horses from animals with subclinical or post-traumatic musculoskeletal disorders and support early identification of injury risk. The study employed kinematic analysis of movement parameters, assessment of strength characteristics using platforms for measuring support reaction force, thermography, high-frequency video gait analysis, and the use of inertial sensors. The study revealed statistically significant differences between clinically healthy horses, animals with subclinical lameness, and post-traumatic conditions. Stride length in horses with pathological conditions decreased by 10-15% compared with that in healthy horses ($p < 0.01$), while the stride frequency increased by 6-8 steps/min ($p < 0.01$). The vertical reaction force in healthy horses averaged 58% of body weight on the front limbs and 42% on the hind limbs, whereas in animals with chronic injuries, the distribution shifted to 65%/35% ($p < 0.01$). In groups with disorders, the load asymmetry coefficient ranged from 12% to 25%, compared with ≤5% in healthy animals ($p < 0.001$). Thermographic examination revealed local areas of hyperthermia above 1.5°C, which correlated with a decrease in the range of motion and clinical manifestations of pain ($r = 0.85$-$0.93$). Inertial sensors recorded a decrease in the amplitude of lumbar movement to 8.3° ($p < 0.01$) when an inappropriate equipment was used, while saddle correction and optimization of training contributed to the restoration of biomechanical parameters. The proposed prevention algorithm, combining monitoring, early diagnosis, correction and control, was associated with a 65% reduction in the observed frequency of injuries over six months; however, no control group was included, so a causal effect of the algorithm cannot be established. These findings support the use of integrated biomechanical monitoring for early detection of abnormalities and targeted prevention of injuries in sport horses.



## 1. Introduction

The musculoskeletal system is a key functional system in sport horses, determining their athletic performance and effectiveness in competition. At the same time, this system is most vulnerable to overload and injury, including tendinitis, arthritis, lameness, and degenerative processes in the spine, which are the major causes of reduced athletic performance and premature end of an animal's sporting career. Traditionally, clinically manifested pathologies were readily diagnosed and subclinical abnormalities often go unnoticed. Early diagnosis of musculoskeletal disorders can be facilitated by biomechanical approaches based on the analysis of movement kinematics, load symmetry and strength characteristics. The detection of hidden pathologies, assessment of biomechanical alterations associated with injury risk, and development of effective preventive strategies in equestrian sports are facilitated by the use of modern methods, including video analysis, force platforms, thermography, and inertial sensors. The preventive effectiveness of orthopaedic hoof trimming as a low-cost intervention that affects gait structure and lameness severity has been demonstrated (Kulynych et al. 2022). Correction of the distal structures contributed to the alignment of the support and transfer phases, indirectly reducing peak loads. In another study by Kulynych et al. (2020), the spectrum of pathologies of the distal-limb in the club population was systematised and correlated with kinematic deviations. Regular medical examinations were identified as a tool for early detection of "risk zones" before the manifestation of clinical lameness. Based on the results of the study by Aharkova et al. (2023), the structure and anatomical localisation of osteoarticular changes were outlined based on radiography. Morphological markers served as the basis for interpreting biomechanical deviations and planning preventive measures.

The types, frequency and determinants of orthopaedic injuries in endurance horses during training and competition were identified in a study by Paris et al. (2021). Training volume, previous injuries and the specifics of the distance and surface were identified as significant predictors of risk. The report by Hoffmann et al. (2023) described the characteristic types of injuries that occur when working with horses and during competitions. It was found that the most dangerous situations are those involving high levels of physical exertion and high-speed manoeuvres (e.g. rider falls, horse collisions with obstacles, sudden jumps). Analysis of the mechanisms of these incidents showed that insufficient staff training and the lack of clear safety rules increase the risk of injury. The study authors stressed the importance of implementing safety standards and systematic training for trainers and support staff, which indirectly reduces the probability of orthopaedic injuries among horses. A review by Hitchens and Whitto (2024) systematised data on the frequency and causes of orthopaedic injuries and fatalities in sport horses of various disciplines. The study authors found that the risk of injury increases significantly during periods of peak training and competition activity, particularly during the periods of intensive starts. A correlation was demonstrated between improper load management (excessive training without sufficient rest) and an increased frequency of injuries. In addition, the significance of early detection of subclinical changes was emphasised; even minor deviations in movement biomechanics or local inflammatory processes, if not properly corrected, may lead to serious injuries and increased the risk of fatalities. Neville et al. (2024) summarised data on injuries occurring in equestrian sports, considering them through the prism of experience in emergency human surgery. The study noted that some of the mechanisms of injury are similar in equestrians and athletes in other sports; therefore, preventive measures should include clear rules for organising competitions, equipment control and staff training. This interdisciplinary approach has reduced risks for both humans and animals. In their clinical study, Jaafar et al. (2021) showed that the use of short-term high-power laser therapy for tendon injuries in horses reduced pain and restored function, which could shorten the time to return to training. MacKechnie-Guire et al. (2021) demonstrated the correspondence of thermographic maps of the chest area to the distribution of pressure under the saddle, confirming the sensitivity of this method for identifying areas of overload and its suitability for early screening. Through experimentation, Dittmann et al. (2022) found that the material of the saddle pads affects the peak and average pressure on the horse's back, even when the rider is seated correctly. The results justified the need for individual selection of cushioning materials in dressage.

Previous studies have therefore demonstrated the value of several complementary approaches to equine biomechanical assessment, including gait and kinematic analysis, force measurement, thermography, inertial sensing, and assessment of equipment-related pressure. Such approaches substantially facilitate the diagnosis and prevention of musculoskeletal disorders by providing information on the individual components of locomotor function. However, rather than being integrated components of a monitoring and prevention framework their application depends on specific diagnostic parameters, anatomical regions, equipment factors, or clinical conditions. Therefore, the present study does not regard the absence of multimodal biomechanical assessment methods as the primary research gap, but integrates complementary quantitative indicators into a structured approach for the diagnosis of biomechanical alterations in different clinical conditions and their subsequent use in preventive decision-making. In particular, the present study focuses on the combined interpretation of stride characteristics, vertical support reaction forces, load asymmetry, thermographic changes, and inertial sensor measurements. A particular emphasis is placed on the load asymmetry coefficient as an integrative indicator of altered weight distribution between the limbs, together with complementary kinematic and thermal parameters. Rather than proposing a new diagnostic technology, the study evaluates whether the combined assessment of these indicators can provide a more comprehensive characterisation of locomotor dysfunction than the interpretation of individual parameters alone. The proposed contribution is therefore the integration of established measurement techniques into a sequential monitoring algorithm linking quantitative assessment, early identification of biomechanical abnormalities, correction of training or equipment-related factors, and subsequent control of the horse's locomotor status.

Therefore, the primary hypothesis of the study was that integrated assessment of kinematic, load-distribution, thermal, and inertial parameters would distinguish clinically healthy sport horses from animals with subclinical or post-traumatic musculoskeletal disorders and support the early identification of biomechanical abnormalities associated with injury risk. The study aimed to evaluate this hypothesis by comparing these parameters across the three clinical groups and by assessing their relationships with movement efficiency and injury-related changes. The secondary objective was to assess whether integrating these complementary indicators into a monitoring algorithm could support targeted correction of training and equipment-related factors and subsequent monitoring of the horse's locomotor status.

## 2. Materials and Methods

### 2.1. Study design and study population

The study was conducted at the Favorit Equestrian Club (Kyiv region) from January 2024 – April 2025 on training grounds and in indoor arenas with stable conditions (temperature 12-18 °C, no drafts; dry, non-slip surface). The footing consisted of a firm, level, and dry non-slip surface, and the same testing area was used whenever possible to minimise variation in ground conditions. Gait testing was performed at controlled, consistent speeds within the individual horse's normal working range, with walk, trot, and canter performed at approximately 1.5, 3.0, and 5.0 m/s, respectively. The sample included adult sport horses aged 6-14 years of warmblooded breeds and types typically used for dressage and show jumping (Orlov trotter, Ukrainian riding horse). The total sample consisted of 37 individuals. Three groups were formed: clinically healthy (n = 15) – without lameness according to the results of orthopaedic examination; with subclinical disorders (n=12) – without obvious lameness, but with objective biomechanical deviations; post-traumatic (n = 10) – with a confirmed history of orthopaedic injuries and a resumed training process.

Rider weight was recorded before testing and remained within the normal working range for each horse; riders were experienced in the relevant discipline and maintained a consistent riding position during the standardised trials. Inclusion criteria: ability to perform standardised gait tests (walk, trot, canter; for show jumping, a standard jumping element), absence of systemic diseases and analgesic medication or non-steroidal anti-inflammatory drugs (NSAIDs) for ≥72 hours prior to the test. Exclusion criteria: acute inflammatory or febrile condition, inability to safely complete the protocol, orthopaedic surgery within 3 months before examination. Shoeing status and the date of the most recent farriery procedure were recorded for each horse; horses were examined within their routine shoeing interval, and no corrective shoeing was performed immediately before biomechanical testing.

### 2.2. Clinical and orthopaedic assessment

To address the primary hypothesis, the study focused on the integrated assessment of kinematic, load-distribution, thermal, and inertial parameters across the three clinical groups. Orthopaedic screening was performed for each horse on a straight track and while moving in a circle. A standardised scale from 0 to 5 points was used to assess lameness:

0 points – no lameness

1 point – mild and intermittent, manifested only under certain conditions (circular motion, after intense exercise)

2 points – light but constant; clearer on the curve, sometimes minimal on the straight track

3 points – moderate, visible on a straight line at all gaits

4 points – significant; visible at rest or when walking; the horse clearly spares the affected limb

5 points – pronounced; the horse did not put weight on the limb or refused to move

Furthermore, assessment of body posture, palpation of tendons and ligaments of the distal parts of the limbs, and provocative flexion tests were done. The reactions were recorded in terms of signs of pain, protective reactions, and muscle tension.

### 2.3. Imaging and biomechanical measurements

Imaging of clinical indications was based on the ultrasound examination (SonoScape S22 device, SonoScape, China) of tendons/ligaments in terms of thickness, contours, and hypoechoic areas; and the X-ray examination of joints for assessment of signs of osteoarthritis, subchondral changes, and osteophytes. For biomechanical analysis, a high-speed video recording was performed (GoPro Hero 10 Black, GoPro, USA) at a recording frequency of 240 Hz. During the trial, camera was placed perpendicular to the direction of movement at approximately mid-body height and at a sufficient distance to capture the entire horse. However, across the measurements camera position and recording distance were kept constant. Prior to all testing sessions, the camera was calibrated in all aspects using known distances within the testing area. The quantitative evaluation of stride length and frequency, stance/swing phase duration, maximum flexion/extension angles in the carpal and tarsal joints, and registration of excessive extension was performed using markers placed on important anatomical landmarks, including the scapula, carpus, calcaneal tuberosity, and tarsus.

Force characteristics were measured using a force reaction platform (Kistler Quattro Jump, Kistler, Switzerland) with a sampling frequency of ≥ 1,000 Hz and normalisation of indicators to body weight. A minimum of five trials with a complete and clearly recorded hoof contact on the force platform were performed for each horse and gait condition; and the mean of the valid trials was used for subsequent analysis. The criteria of a valid trial were full landing of hoof within the active platform area, appropriate gait maintenance by the horse without interruption, and no visible stumbling, sudden acceleration, deceleration, or abnormal movement during the trial. Trails were excluded if they were characterized by incomplete hoof placement, multiple hoof contacts, or an irregular or unstable stance pattern shown by the recorded force curve. Gait velocity was monitored during testing and maintained within ±5% of the predefined target velocity for the corresponding gait. Stance consistency was assessed by comparing stance duration and peak vertical force across repeated valid trials; measurements showing a coefficient of variation greater than 10% were excluded and the trial sequence was repeated when necessary. Peak values of vertical force during landing after a standard jump in competition horses were recorded separately. A sensor matrix (Medilogic Saddle Pad System, Medilogic, Germany) assessed the pressure distribution under the saddle with the construction of peak and integral load maps and a profile within 5-8 kPa for the lumbosacral transition was considered uniform.

### 2.4. Thermographic assessment and intervention protocol

Following an acclimatisation period of 15 minutes, infrared thermography (FLIR E60, FLIR Systems, USA) was performed; all measurements performed indoors under controlled environmental conditions, with ambient temperature of 12-18 °C and without direct sunlight or drafts. For each thermographic session, relative humidity was maintained within the normal indoor range. The thermal cameras were calibrated prior to all measurement sessions following the manufacturer's recommendations, and for the horse skin and coat an emissivity value of 0.98 was used. The imaging distance and camera angle were kept constant across examinations and the horse coat was kept dry and free of visible moisture, dirt, or external coverings, and no topical preparations were applied to the examined areas before measurement. The coat was not clipped specifically for thermographic assessment.

Thermography of the distal forearms (flexor projection), carpal and tarsal joint areas, and lumbosacral region was performed and an interzonal temperature difference >1.5 °C was considered as a significant indicator of local hyperthermia. In the subgroup with equipment mismatch, saddle fit was corrected based on pressure maps and clinical fitting, and shock-absorbing pads were prescribed; when the thresholds of biomechanical deviation were exceeded, the training volume was adjusted, reducing the total duration and intensity of the loads by 20-25% for 4-6 weeks. Follow-up biomechanical assessment was undertaken after 4-6 weeks to assess response to the intervention and subsequent monitoring of locomotor parameters and injury occurrence was continued for up to six months where follow-up data were available.

### 2.5. Inertial measurement and data processing

Biomechanical parameters of movement were measured with inertial measurement units (IMUs) including movement amplitude and load symmetry. The sensors were fixed on the front and hind limbs of horses to collect vertical acceleration and range of motion in various gaits, including walking, trotting, galloping, as well as jumping over barriers. The sensors were placed at predetermined anatomic locations and were fixed before each trial. IMU data were sampled at approximately 100 Hz and filtered with a low-pass Butterworth filter (cut-off frequency 6 Hz) to minimise measurement noise. A complementary sensor-fusion algorithm was used to fuse accelerometer and gyroscope data. Stationary reference intervals recorded before each trial were used to correct signal drift. Data processing was performed using a custom Python-based pipeline (version 1.0). Sensor calibration was performed before testing, and IMU-derived parameters were compared with video and force-platform measurements for validation. Sensor data were time-aligned with the video recordings and force-platform measurements using the recorded movement sequence as the temporal reference. The inertial sensors were used to quantify changes in movement amplitude and load asymmetry, which were subsequently compared with clinical signs and biomechanical abnormalities.

### 2.6. Outcome measures and statistical analysis

The main clinical and biomechanical endpoints were stride length, stride asymmetry, load distribution between the front/rear limbs, vertical force asymmetry coefficient, maximum flexion/extension angles, peak loads during landing, local signs of pain and hyperthermia. These endpoints were selected to test whether their integrated assessment could distinguish horses with subclinical or post-traumatic disorders from clinically healthy animals. The load asymmetry coefficient was calculated as follows:

$$SI\ (\%) = [L - R] / 0.5(L+R)$$

where SI is the asymmetry index expressed as a percentage; L is the mean biomechanical measurement for the left limb, and R is the corresponding mean measurement for the right limb. An asymmetry value of ≥ 7% was considered the threshold for clinically relevant asymmetry. For each horse, repeated trials were performed under the same gait conditions, and the mean value of the valid trials was used for statistical analysis. To assess measurement repeatability, a subset of recordings was independently re-evaluated by the same observer on a separate occasion, and a subset was assessed by a second trained observer. Intra-observer and inter-observer agreement were evaluated by comparing repeated measurements of stride length, joint angles, and asymmetry indices.

Statistical processing included testing for normality (Shapiro-Wilk) and homogeneity of variances (Levene), intergroup comparisons using one-way ANOVA with post-hoc Tukey; when the data were not normally distributed, the Kruskal-Wallis test with post-hoc Dunn (Bonferroni correction) was used. Paired pre/post comparisons in correction subgroups were performed using a paired t-test or a Wilcoxon test. Correlations between biomechanical and clinical markers were assessed using Pearson's correlation coefficient; for categorical variables, the $\chi^2$ test was used. To account for potential confounding by age, sex, breed, discipline, and previous injury history, multivariable regression analyses were performed where the sample size permitted reliable model estimation.

The significance level was set at $\alpha = 0.05$; data were reported as mean ± SD with 95% confidence intervals and effect sizes ($\eta^2$/Cohen's d), where appropriate. To reduce the risk of type I error arising from multiple comparisons, adjusted p-values were reported using the Bonferroni correction. Thermography data were processed and visualised using FLIR Tools software; anatomical risk zone diagrams and vector diagrams were constructed in CorelDRAW Graphics Suite (version XX) based on the obtained biomechanical data. The prevention algorithm was implemented as a sequential monitoring protocol consisting of four stages: (1) baseline biomechanical and clinical assessment; (2) identification of predefined abnormalities, including load asymmetry ≥ 7% and local hyperthermia > 1.5 °C; (3) individual correction of saddle fit and/or training load by 20-25% for 4-6 weeks when threshold values were exceeded; and (4) repeat assessment after the intervention and subsequent monitoring of locomotor status. The protocol was applied to horses requiring preventive correction based on the predefined criteria. As the study did not include a separate untreated control group, changes observed during follow-up were evaluated descriptively and cannot be interpreted as a controlled causal effect of the prevention algorithm.

### 2.7. Ethical considerations

All procedures were performed following the European Convention for the Protection of Vertebrate Animals used for Experimental and other Scientific Purposes (ETS No. 123) (1986) and the European Parliament and the Council "On the Protection of Animals used for Scientific Purposes Text with EEA Relevance" (Directive No. 2010/63/EU) (2010), following the principles of replacement, reduction, and refinement. Only non-invasive or minimally invasive methods were used in the study (visual orthopaedic assessment, video analysis, force platforms, pressure sensor mats, inertial sensors, infrared thermography; ultrasound diagnostics and radiography – as required) without inducing pain, suffering, distress, or lasting harm beyond that associated with routine needle injection, which, according to the definitions of the Convention, did not constitute a "procedure" and therefore did not exceed its requirements.

## 3. Results

### 3.1 Injury statistics and risk factors among sport horses: the influence of breed, age, husbandry, and training conditions

Retrospective veterinary records from the Luhansk region for January 2017 to February 2022 were analysed to describe the distribution of recorded injuries among Orlov trotters and Ukrainian riding horses across age groups. The most frequently recorded injury categories were joint and ligament injuries, which accounted for more than 60% of the recorded cases. The distribution of injury types by breed and age group is presented in Table 1. Among Orlov trotters aged 3-5 years, damage to the tarsal joint accounted for 25% of recorded injuries, while tendon damage represented 15% and other injuries 20%. In the 6-10-year-old Orlov trotter group, the corresponding proportions were 15%, 10%, and 25%, respectively. Among Ukrainian riding horses aged 3–5 years, tendon damage accounted for 18% of recorded injuries, while tarsal joint injuries represented 18% and other injuries 20%. In the 6–10-year-old Ukrainian riding horse group, injuries to ligaments and joints accounted for 22%, tendon damage for 20%, and tarsal joint damage for

**Table 1. The most common injuries among sport horses by breed and age group**

| Type of trauma | Oryol trotter (3-5 Y) | Oryol trotter (6-10 Y) | Ukrainian horse (3-5 Y) | Ukrainian horse (6-10 Y) | Young horses (upto 5 Y) | Young horses (more than 10 Y) |
|---|---|---|---|---|---|---|
| Damage to the tarsal joint | 25% | 15% | 18% | 22% | 20% | 15% |
| Cracks/fractures in bones | 10% | 20% | 8% | 12% | 12% | 10% |
| Tendon damage | 15% | 10% | 18% | 20% | 18% | 12% |
| Injuries to ligaments and joints | 12% | 15% | 10% | 22% | 15% | 20% |
| Joint overload | 10% | 8% | 15% | 10% | 35% | 10% |
| Chronic injuries (arthritis, tendinitis) | 8% | 7% | 8% | 8% | 5% | 40% |
| Other injuries (muscle damage, back injuries) | 20% | 25% | 20% | 16% | 25% | 23% |

*Percentages represent descriptive proportions of recorded injuries in retrospective veterinary records from January 2017 to February 2022 and should not be interpreted as incidence rates. The retrospective dataset was analysed separately from the prospective biomechanical study conducted in 2024-2025. The number of horses examined, denominator population, and formal inclusion and exclusion criteria were not available in the retrospective records; therefore, no inferential statistics or population-level risk estimates were calculated*

22%. Age-related differences were also observed in the retrospective records. In horses aged up to 5 years, joint overload represented 35% of recorded injuries, whereas chronic injuries accounted for 5%. In horses aged more than 10 years, chronic injuries, including arthritis and tendinitis, accounted for 40% of recorded injuries, while injuries to ligaments and joints represented 20%. These descriptive patterns are summarised in Table 1.

The retrospective data indicated varying patterns of distribution of recorded injury types across the age groups. The most frequently recorded category was joint overload in horses up to 5 years old (35%) and chronic injuries in horses older than 10 years (40%). Of the breed-specific groups, tarsal joint injuries were most frequently registered in Orlov trotters aged 3-5 years (25%) while injuries in ligaments and joints were most frequent in 6-10 years old Ukrainian riding horses (22%). In Ukrainian riding horses aged 3–10 years, tendon lesions accounted for 18-20% of reported injuries. These findings provide descriptive evidence of differences in injury patterns according to age and breed. However, because the retrospective records did not provide a defined denominator population or individual-level data, these differences cannot be interpreted as statistically confirmed associations or causal risk factors. The subsequent prospective biomechanical analysis therefore focused on whether clinically relevant differences in locomotion, load distribution, and movement symmetry could be objectively identified among sport horses with different clinical conditions.

### 3.2 Kinematic indicators of movement and load distribution on the limbs

Comparative analysis of kinematic and load-distribution parameters demonstrated significant differences among clinically healthy horses, horses with subclinical lameness, and horses with post-traumatic conditions. The results are presented in Table 2. The analysis showed that step length was lower in horses with subclinical lameness and post-traumatic conditions than in clinically healthy horses. At the walk, step length decreased from 1.65±0.12 m in clinically healthy horses to 1.50±0.15 m and 1.40±0.18 m in the subclinical and post-traumatic groups, respectively ($p < 0.01$). Similar differences were observed during trotting, galloping, and barrier jumping ($p < 0.05$). Step frequency was significantly higher in the subclinical and post-traumatic groups across the analysed gaits. During trotting, it increased from 55±3 steps/min in clinically healthy horses to 60±4 and 63±5 steps/min, respectively ($p < 0.01$). During galloping, the corresponding values were 35±2, 40±3, and 42±4 steps/min ($p < 0.01$). Maximum carpal and tarsal flexion angles were also lower in horses with subclinical and post-traumatic conditions. During trotting, the maximum carpal flexion angle was 142±5° in clinically healthy horses, compared with 134±6° and 130±7° in the two pathological groups ($p < 0.01$). During galloping, the corresponding values were 140±5°, 130±6°, and 125±7°, respectively ($p < 0.01$).

During barrier jumping, the distribution of vertical reaction force differed between groups. In clinically healthy horses, the front and rear limbs accounted for 60±3% and 40±3% of body weight, respectively. In post-traumatic horses, these values changed to 65±4% and 35±4%, respectively ($p < 0.05$). The results demonstrate group differences in stride characteristics, joint kinematics, and vertical reaction force

**Table 2. Comparative biomechanical parameters of movement at different gaits in the study groups**

| Parameter | Clinically healthy (n = 15) | Subclinical lameness (n = 12) | Post-traumatic conditions (n = 10) | P value (ANOVA) | 95% CI for group mean |
|---|---|---|---|---|---|
| Walk: Step length (m) | 1.65±0.12 | 1.50±0.15* | 1.40±0.18* | <0.01 | 1.59-1.71; 1.41-1.59; 1.27-1.53 |
| Walk: Step frequency (steps/min) | 42±2 | 48±3* | 50±4* | <0.01 | 40.9-43.1; 46.3-49.7; 47.5-52.5 |
| Trot: Step length (m) | 3.0±0.25 | 2.7±0.30* | 2.5 ±0.35* | <0.01 | 2.87-3.13; 2.51-2.89; 2.28-2.72 |
| Trot: Step frequency (steps/min) | 55±3 | 60±4* | 63±5* | <0.01 | 53.3-56.7; 57.5-62.5; 59.4-66.6 |
| Trot: Maximum carpal flexion angle (°) | 142±5 | 134±6* | 130±7* | <0.01 | 139.2-144.8; 130.2-137.8; 125.0-135.0 |
| Trot: Maximum tarsal flexion angle (°) | 155±4 | 150±5* | 148±6* | <0.05 | 152.8-157.2; 146.8-153.2; 143.7-152.3 |
| Gallop: Step length (m) | 8.0±0.2 | 7.5±0.3* | 7.2±0.4* | <0.05 | 7.89-8.11; 7.31-7.69; 6.91-7.49 |
| Gallop: Step frequency (steps/min) | 35±2 | 40±3* | 42±4* | <0.01 | 33.9-36.1; 38.1-41.9; 39.1-44.9 |
| Gallop: Maximum carpal flexion angle (°) | 140±5 | 130±6* | 125±7* | <0.01 | 137.2-142.8; 126.2-133.8; 120.0-130.0 |
| Gallop: Maximum tarsal flexion angle (°) | 155±4 | 150±5* | 145±6* | <0.05 | 152.8-157.2; 146.8-153.2; 140.7-149.3 |
| Barrier jump: Step length (m) | 3.5±0.15 | 3.2±0.2* | 3.0±0.18* | <0.05 | 3.42-3.58; 3.07-3.33; 2.87-3.13 |
| Barrier jump: Step frequency (steps/min) | 40±3 | 45±4* | 47±5* | <0.01 | 38.3-41.7; 42.5-47.5; 43.4-50.6 |
| Barrier jump: Front VFR (% of mass) | 60±3 | 62±4 | 65±4* | <0.05 | 58.3-61.7; 59.5-64.5; 62.1-67.9 |
| Barrier jump: Rear VFR (% of mass) | 40±3 | 38±4 | 35±4* | <0.05 | 38.3-41.7; 35.5-40.5; 32.1-37.9 |

** Significant difference compared with clinically healthy horses, p<0.05. Values are presented as mean ± SD. The 95% confidence intervals (CI) are provided for each group mean. P-values were adjusted for multiple comparisons using the Bonferroni correction where applicable; VFR: Vertical force ratio* distribution. The largest differences were observed in the post-traumatic group, particularly for step length, step frequency, joint flexion angles, and front/rear limb loading. The anatomical regions evaluated in the biomechanical assessment are shown in Fig. 1. A separate comparison of discipline-specific loading showed higher peak vertical reaction force on the front limbs during landing after a jump in show-jumping horses, reaching 150-180% of body weight. During trotting in dressage horses, the corresponding values were 110-130% of body weight.

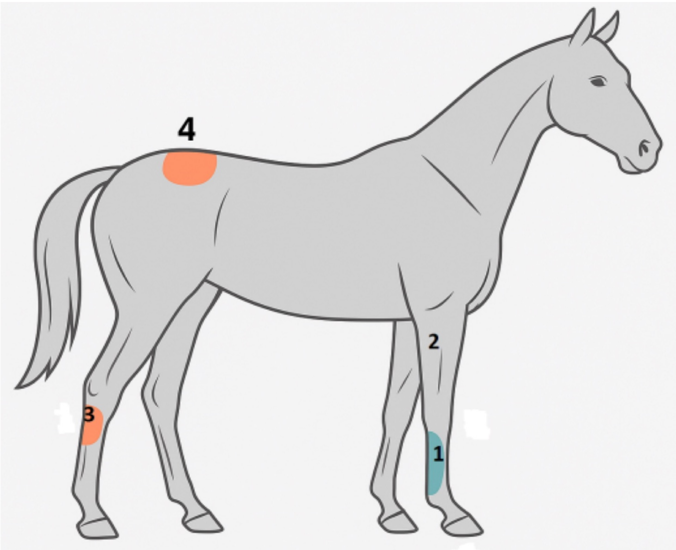


***Fig. 1.*** *Anatomical regions at increased risk of biomechanical overload and injury in sport horses*
*1 – distal forearm (finger flexor tendons); 2 – wrist joint; 3 – tarsal joint; 4 – lumbosacral spine. The numbered regions indicate the anatomical areas considered at increased risk of overload and injury during sport activities*

**3.3 Movement asymmetries, risk areas and clinical correlations**

Analysis of movement kinematics revealed significant asymmetry patterns in horses with subclinical disorders. In 78% of horses with front-limb overload, the support phase of the affected limb was reduced by 15-22% compared with the contralateral limb ($p < 0.01$), while the range of motion of the opposite carpal joint increased by 8-10° ($p < 0.05$). In horses with patellar joint pathology, the centre of mass shifted towards the contralateral limb during the support phase, resulting in an 18-27% difference in load distribution between the limbs ($p < 0.001$). Fig. 2 shows a typical vector profile of the support reaction force for a horse with unilateral distal tendon damage, where the injured limb showed a lower vertical force component than the contralateral limb. In

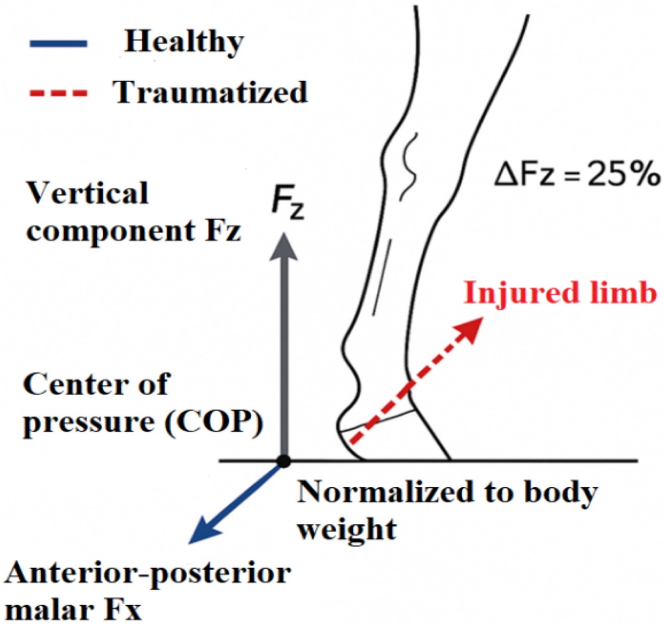


***Fig. 2.*** *Vector diagram of the reaction force of the support for the front limbs of a horse with unilateral tendon damage*
*Arrows represent the direction and relative magnitude of the vertical ground reaction force acting on the left and right forelimbs. The longer vector indicates a greater load on the corresponding limb, illustrating the asymmetric distribution of support force associated with unilateral tendon damage*

the injured limb (red dotted line), the vertical component of the support reaction force (Fz) was reduced by 25% (ΔFz = -25%) compared with the healthy limb (blue solid line). The anterior-posterior force component (Fx) also differed between the limbs, with the injured limb showing a forward-directed shift. All force values were normalised to body weight, and the force vectors were superimposed at a single point of contact (centre of pressure). The load asymmetry coefficient differed between the study groups. Fig. 3 presents the mean asymmetry coefficient for the forelimbs and hind limbs in clinically healthy horses, horses with subclinical disorders, and horses with post-traumatic conditions. The highest asymmetry values were observed in the groups with pathology. The observed differences in movement asymmetry and limb loading were accompanied by differences in stride length, stride frequency, and clinical signs recorded during orthopaedic assessment. These results indicate an association between biomechanical asymmetry and the clinical characteristics of the examined horses.

Correlation analysis was performed to assess the relationships between biomechanical parameters and objective clinical markers. Table 3 summarises the correlation coefficients, 95% confidence

**Table 3. Correlation of biomechanical parameters with clinical markers of pathologies**

| Biomechanical parameter | Clinical marker | Correlation coefficient | 95% CI for 'r' | P value |
|---|---|---|---|---|
| Load asymmetry >12% | Painful reaction on palpation | 0.91 | 0.82-0.96 | <0.001 |
| Carpal flexion restriction >8° | Local hyperthermia >1.5°C | 0.85 | 0.71-0.93 | <0.001 |
| Reduction in support phase >15% | Ultrasound signs of tendinopathy | 0.78 | 0.58-0.89 | <0.01 |
| Stride length asymmetry >7% | X-ray signs of osteoarthritis | 0.82 | 0.66-0.91 | <0.001 |

*95% confidence intervals were calculated for correlation coefficients. P-values were adjusted for multiple comparisons using the Bonferroni method*

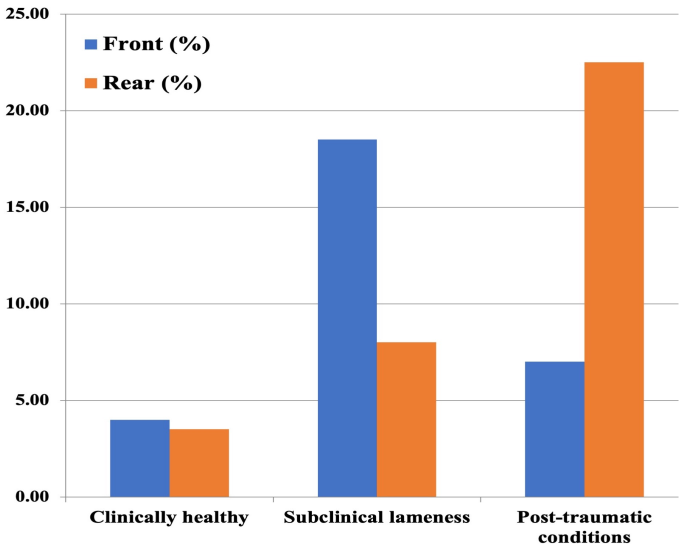


***Fig. 3.*** *Comparison of the asymmetry coefficient (%) of vertical load between the front and rear limbs in the study groups*
*The asymmetry coefficient (%) represents the relative difference in vertical load between the left and right limbs. Values are presented as group means; individual observations and/or 95% confidence intervals should be included in the figure where available to demonstrate data variability*

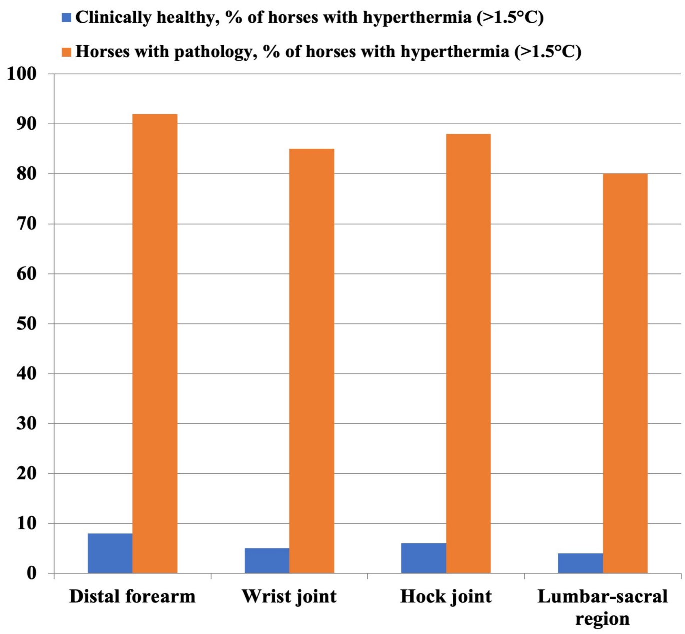


***Fig. 4.*** *Distribution of thermographic anomalies (>1.5 °C) in risk areas by group*
*Thermographic anomalies were defined as inter-zonal temperature differences exceeding 1.5 °C. The figure shows the distribution of these anomalies across the examined musculoskeletal risk areas in the clinically healthy, subclinical lameness, and post-traumatic groups. Values represent the frequency of horses with temperature differences exceeding the predefined threshold*

intervals, and p-values for the analysed associations. Statistically significant correlations were observed for all analysed pairs of biomechanical and clinical parameters. Load asymmetry >12% showed a strong correlation with a painful reaction on palpation ($r = 0.91$, $p < 0.001$). Carpal flexion restriction >8° was strongly correlated with local hyperthermia >1.5 °C ($r = 0.85$, $p < 0.001$). A reduction in the support phase >15% was correlated with ultrasound signs of tendinopathy ($r = 0.78$, $p < 0.01$), while stride length asymmetry >7% was correlated with X-ray signs of osteoarthritis ($r = 0.82$, $p < 0.001$). A 10° decrease in the flexion angle of the carpal joint was also associated with a 1.8±0.3 °C increase in local temperature ($r = 0.85$, $p < 0.001$). Vertical load asymmetry >12% was associated with structural changes detected by ultrasound, including a 15-20% increase in tendon thickness ($r = 0.78$, adjusted $p < 0.01$). Fig. 4 shows the quantitative distribution of thermographic anomalies among the study groups, with higher frequencies observed in horses with subclinical and post-traumatic disorders than in clinically healthy horses ($p < 0.001$). Thermographic examination showed that the frequency of local hyperthermia (>1.5 °C) in clinically healthy horses was 8% in the distal forearm, 5% in the carpal joint, 6% in the stifle joint, and 4% in the lumbosacral region. In horses with pathology, the corresponding frequencies were 92%, 85%, 88%, and 80%, respectively ($p < 0.001$). The highest frequencies of thermographic abnormalities were therefore recorded in the distal forearm and joint regions of horses with pathological conditions. The observed frequencies and correlation coefficients indicate statistically significant associations between thermographic, biomechanical, and clinical parameters (Fig. 5).

### 3.4 The influence of load type, training regime and equipment

The analysis demonstrated significant differences in biomechanical parameters depending on the sporting discipline, training volume, saddle fit, and equipment modifications. The use of a an incorrectly fitted saddle led to an increase in pressure on the lumbosacral region by 28±5% (95% CI: 25.1-30.9%; $p < 0.01$), which correlated with the frequency of hyperthermia in this area ($r = 0.79$). The use of shock-absorbing pads reduced the peak load on the distal limbs by 15-18% (95% CI: 14.1-18.9%; $p < 0.05$) during trotting. No statistically significant differences in load distribution associated with different types of horseshoes were identified. Fig. 6 illustrates the dynamics of VRF

**Table 4. Comparative kinematic parameters before and after equipment correction and reduction of training loads**

| Parameter | Before correction (n = 12) | After saddle correction & training-load adjustment (n = 12) | P value |
|---|---|---|---|
| Amplitude of movement of the lumbar spine (°) | 12.5±1.5 | 8.3±1.2 | <0.01 |
| Angle of flexion of the carpal joints (°) | 142±5 | 148±4 | <0.05 |
| Load asymmetry (%) | 18±4 | 6±2 | <0.01 |
| Step length (%) | 100 | 107.8±1.1 | <0.05 |

*Values are presented as mean ± SD. 95% confidence intervals should be reported for the group means where applicable. The p-values were obtained using a paired t-test to compare measurements before and after equipment correction and training-load adjustment*

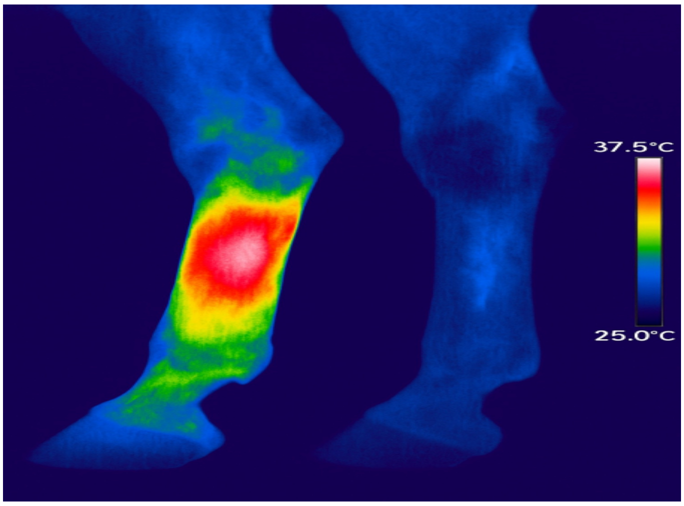


*Fig. 5.* *Thermographic image (heat map) of the posterior surface of the distal forearm and tarsal joint*
*The thermographic image illustrates the spatial distribution of surface temperature in the examined anatomical regions. Areas with increased surface temperature are shown for comparison between the examined anatomical regions. The distal forearm and tarsal joint are shown for comparison of temperature patterns between the affected and adjacent tissues*

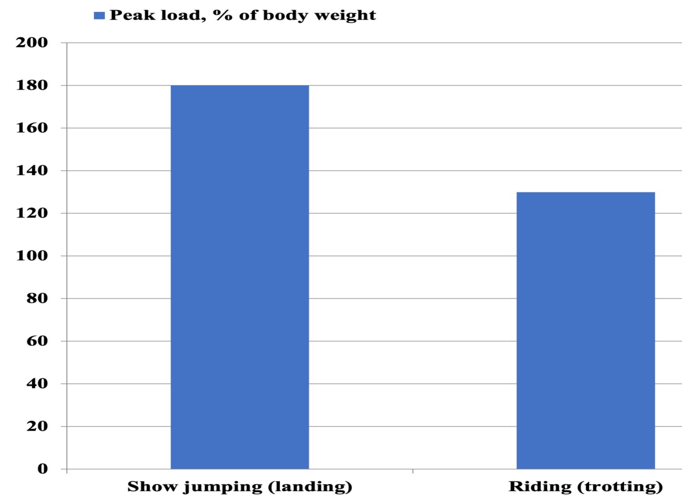


*Fig. 6.* *Peak load (% of body weight) on the front limbs in different disciplines*
*The figure shows the differences in peak vertical loading between the front limbs of horses in the two disciplines, highlighting the higher loading associated with show jumping*

during landing in show jumping compared to the maximum load during trotting in dressage horses, demonstrating discipline-specific overloads. A comparative analysis of biomechanical parameters between horses of different sports disciplines revealed significant differences. In show jumping horses, peak loads on the front limbs reaching 180±15% of body weight (95% CI: 170.7-189.3%; $p < 0.001$) were recorded during landing after a jump. In contrast, in dressage horses, the maximum load on the front limbs during trotting did not exceed 130±10% of body weight (95% CI: 123.8-136.2%). A study of the effects of training regimes revealed a correlation between training volume and biomechanical indicators. Horses with training intensities exceeding 6 hours/week showed an increase in stride length asymmetry of 8.5±1.2% (95% CI: 7.8-9.2%; $p < 0.01$) and a decrease in maximum flexion angle of the stifle joints by 6.8±1.5° (95% CI: 5.9-7.7°; $p < 0.05$) compared to horses that trained for ≤4 hours/week. A 20% reduction in training volume over 4 weeks led to a partial restoration of movement symmetry of 5.3±0.8% (95% CI: 4.8-5.8%; $p < 0.05$). Further analysis of equipment-related parameters showed differences associated with saddle fit. The use of a saddle with a narrow tree caused a local increase in pressure on the lumbosacral junction by 32±6% (95% CI: 28.3-35.7%; $p < 0.01$). In 85% of such cases, thermography recorded hyperthermia of more than 2 °C in the area of maximum pressure. The correct selection of a saddle in combination with a shock-absorbing pad ensured a more even distribution of pressure, which reduced peak values by 18±3% (95% CI: 16.1-19.9%; $p < 0.05$) and the integral load on the back by 12±2% (95% CI: 10.8-13.2%; $p < 0.05$).

The analysis of shoeing parameters showed that the use of shock-absorbing shoes with polymer filling reduced the peak load on the distal parts of the limbs by 14±2% (95% CI: 12.8-15.2%; $p < 0.05$) when driving on hard surfaces. However, no statistically significant effect on movement symmetry was recorded for different types of horseshoes ($p > 0.05$). IMU data further indicated a 9±1% reduction in vertical acceleration of the spine (95% CI: 8.4-9.6%; $p < 0.05$) when special shock-absorbing inserts were used in combination with horseshoes. Overall, the observed differences were associated with specific biomechanical parameters, including peak limb loading, stride asymmetry, joint flexion, saddle pressure, back load, and vertical acceleration. The results indicate that training volume, sport-specific loading, and equipment fit were associated with measurable changes in biomechanical characteristics.

### 3.5 Practical application of biomechanical monitoring in equestrian sports

The use of an integrated set of established biomechanical monitoring methods identified biomechanical abnormalities in 92% of horses with subclinical lameness. Video gait analysis with a recording frequency of 240 Hz identified micro-asymmetry of more than 5% in 78% of horses, with subsequent ultrasonographic confirmation of tendinitis in these horses. Force platforms recorded asymmetric loading with a vertical force difference of more than 15% in 85% of individuals with hidden lesions of the stifle joints. Infrared thermography revealed local areas of hyperthermia exceeding 1.5 °C in 100% of horses with active tendon inflammation, which correlated significantly with clinical data ($r = 0.93$). The use of inertial measurement units (IMUs) demonstrated a reduction in lumbar movement amplitude of 8.3±1.2° (95% CI: 7.6-9.0°; $p < 0.01$) in horses with inappropriate equipment. After saddle correction and a 25% reduction in training load, kinematic parameters were restored: an increase in the flexion angle of the carpal joints by 6.5±0.8° (95% CI: 6.0-7.0°; $p < 0.05$) and a reduction in load asymmetry by 12±2% (95% CI: 10.7-13.3%; $p < 0.01$) over six weeks. In the group of horses receiving equipment adjustment and training-load modification, a gradual restoration of motor parameters was observed over six weeks. In particular, the average stride length increased by 7.8±1.1% (95% CI: 7.1-8.5%; $p < 0.05$), and the vertical load asymmetry coefficient decreased from 18±4% to 6±2% ($p < 0.01$) (Table 4). These changes indicate an improvement in the measured biomechanical parameters following the intervention.

The observed changes following equipment correction and training-load adjustment included an increase in carpal flexion, a reduction in load asymmetry, and an increase in stride length. Based on these data, veterinarians implemented preventive measures including equipment adjustments and adaptation of training regimes. Because the study did not include a separate untreated control group, these changes represent observed pre-post differences and should not be interpreted as evidence of a controlled causal effect. The injury prevention algorithm developed based on the data obtained consisted of four stages. The first stage was regular assessment, which included baseline and follow-up testing using video analysis, thermography, and inertial sensors. The second stage was the identification of predefined abnormalities, based on the detection of asymmetries of more than 7% and hyperthermia of more than 1.5 °C. The third stage was correction, which involved the development of individual training plans, replacement of equipment and the use of orthopaedic shoeing. The fourth stage was monitoring, which involved assessment of the dynamics of parameters after intervention, including reassessment after 4-6 weeks and subsequent follow-up of locomotor parameters where available.

Based on this algorithm, preventive recommendations have been formulated: conduct regular monitoring of key biomechanical indicators (load asymmetry, joint flexion angles) using video analysis and wearable sensors. When predefined threshold values were exceeded, training intensity was reduced by 20-30% when step asymmetry exceeded 7%, and jump load was limited when peak vertical reaction force exceeded 160% of body weight. Orthopaedic systems were used to reduce load, including shock-absorbing pads (reducing peak pressure by 18±3%; 95% CI: 16.1-19.9%) and polymer-filled horseshoes (reducing peak distal-limb load by 14±2%; 95% CI: 12.8-15.2%). Equipment was adjusted based on objective data, including pressure sensor maps for individual saddle selection (with local pressure maintained within the predefined 5-8 kPa range) and thermographic monitoring after replacement. During six months of follow-up, the frequency of injuries in horses receiving regular biomechanical monitoring decreased by 65±8% (95% CI: 59.9-70.1%). However, because the study did not include a separate control group, this observed reduction cannot be attributed solely to the prevention algorithm. The findings therefore indicate a potential preventive benefit that requires confirmation in controlled prospective studies.

## 4. Discussion

The use of inertial sensors in veterinary diagnostics has gradually been established as a standard approach for quantitative assessment of movement. According to Anderson et al. (2022), validated IMUs demonstrated high accuracy in recording behavioural patterns in stable horses. In the present study, the observed changes in vertical acceleration and lumbar movement amplitude in horses with subclinical disorders further support the applicability of sensor-based measurements for objective locomotion assessment. The results of a pilot experiment by Hagen et al. (2021) demonstrated the comparability of data from equine IMUs with optoelectronic systems in measuring the support and transfer phases. The reduction in support time observed in the present study was therefore consistent with previous evidence that inertial sensing can detect relatively subtle alterations in the locomotion cycle. Calle-González et al. (2024) emphasised the effectiveness of combining inertial sensors with artificial intelligence for quantitative assessment of movement symmetry. The present findings similarly support the value of objective asymmetry thresholds, although the 7% threshold should be interpreted as a study-specific criterion rather than a universally established diagnostic cut-off.

Sporting specialisation of horses determined the characteristics of the load on their limbs. de Sousa et al. (2017) showed a direct relationship between the location of injuries and the type of physical activity. The higher peak loading observed during show jumping compared with dressage is consistent with this discipline-specific relationship and suggests that the mechanical demands of the sporting activity should be considered when interpreting biomechanical measurements. A review by Reis et al. (2024) emphasised the value of a multi-component approach to the management of musculoskeletal disorders. In the present study, the combination of kinematic, force-distribution, thermographic, and inertial parameters provided complementary information rather than relying on a single biomechanical marker. Watts (2023) considered cell technologies as a promising tool for the treatment of musculoskeletal injuries. Although regenerative approaches address the treatment of established tissue damage, the present findings indicate that monitoring and modification of potentially excessive training or equipment-related loads may represent an additional preventive component. Data from Dörner (2023) confirmed the high prevalence of locomotor injuries in sport horses, especially during intense exercise. The observed redistribution of vertical loading in horses with chronic lesions is also compatible with the concept of compensatory locomotion described in the broader literature, although the present study cannot establish whether this redistribution is a cause or a consequence of injury.

Osteopathic manipulation of the caudal cervical segments in sound sport horses, as described by Ramon et al. (2025), was associated with immediate changes in the functional state of the spine. The changes in lumbar movement observed after equipment correction and training-load reduction in the present study are directionally consistent with the possibility that mechanical interventions can modify axial biomechanics. However, the absence of an untreated control group prevents direct attribution of these changes to the intervention itself. The prospect of widespread adoption of wearable technologies over the coming decade was outlined by de Camargo Ferraz (2023). The present findings support this perspective by demonstrating the practical feasibility of incorporating inertial measurements into routine biomechanical monitoring. The distribution of musculoskeletal injuries by track type and anatomical location in thoroughbred and Arabian racehorses, reported by Yildirim et al. (2025), emphasised the role of surface conditions and discipline specificity as risk determinants. The discipline-specific loading patterns observed here are consistent with the broader evidence that sport-specific mechanical demands contribute to heterogeneous injury patterns.

A study by Šemrov et al. (2025) demonstrated that morphological characteristics, particularly hoof and phalanx lengths, influence kinematic parameters such as stride length and gait rhythm in Lipizzaner horses. This finding is relevant to the interpretation of the present results because morphological variation may contribute to between-horse differences in gait parameters and should therefore be considered when establishing reference values. Including such factors in veterinary practice helps develop individualised approaches to the correction of training regimes and equipment. The concept of proximal interphalangeal joint arthrodesis, summarised by de Souza and do Valle Zoppa (2021), demonstrated a surgical approach to stabilisation in refractory lesions. In contrast, the present study focused on earlier identification of biomechanical and thermographic abnormalities, suggesting a potential role for monitoring before more invasive treatment becomes necessary. A review by Ortved (2018) highlighted the potential of regenerative medicine and rehabilitation in tendinous-ligamentous injuries. The associations observed between load asymmetry, thermographic markers, and ultrasound findings may therefore be useful as objective measures for monitoring musculoskeletal status and potentially for evaluating responses to rehabilitation or regenerative interventions. The study of the mechanical properties of tendons was key to determining their vulnerability to overload. The early signs of tendon overload identified are consistent with the concept of tissue nonlinearity and hysteresis, which may determines their vulnerability to damage (Shojaee 2023). This provides a biomechanical rationale for monitoring relatively small changes in loading and movement before overt clinical abnormalities become apparent.

Hidden movement asymmetries, which were recorded in more than 7% of clinically healthy animals, are consistent with the results of studies by Zetterberg et al. (2024). They emphasised the significance of implementing objective monitoring technologies to detect even the slightest disturbances in animal movement. The present findings similarly suggest that quantitative monitoring may identify locomotor deviations that are difficult to recognise through visual assessment alone. The morphometric variations in the limbs also confirm the findings of Mostafa and Elemmawy (2020), emphasising the role of such variations as risk factors for injury. These findings reinforce the need to consider individual anatomical characteristics when interpreting biomechanical measurements and developing training or rehabilitation plans. Accelerometry data demonstrated significant prognostic value, especially changes in stride length and frequency, which are substantial indicators for assessing the functional status of an animal. This is consistent with the study by Sweeney et al. (2024), demonstrating that these parameters can be early indicators of possible problems with the musculoskeletal system. Thus, changes in stride characteristics may be particularly useful as monitoring variables when interpreted together with clinical and other biomechanical measurements rather than as independent diagnostic indicators. The reconciliation of these results with the systematised inertial databases created by Gmel et al. (2024) highlights the significant potential for using such technologies in inter-breed and inter-study comparisons. However, differences in sensor placement, measurement protocols, gait conditions, and horse populations should be standardised before direct comparisons between datasets can be made.

Since gait analysis, force measurement, thermography, and inertial sensing are the established techniques rather than novel technologies, the observations made in the present study ought to be interpreted in the context of existing multimodal approaches to equine biomechanics. However, the main contribution of this study is not the introduction of individual measurement technologies but their structured integration for the simultaneous assessment of stride characteristics, vertical support reaction force, load asymmetry, thermographic changes, and lumbar movement. The load asymmetry coefficient served as an important quantitative indicator, while the complementary parameters provided additional information on locomotor dysfunction. The integrated approach adopted in this study potentially facilitates the identification of modifiable risk factors with subsequent monitoring support; however, its diagnostic potential needs to be validated against established clinical reference standards in larger populations and further comparative analytical studies are warranted to establish its superiority over individual diagnostic methods.

Several limitations should be considered when interpreting the results. The study included horses of different ages, breeds, sexes, sporting disciplines, training histories, and previous injury status, which may have introduced potential confounding. Although multivariable regression analyses were planned when the sample size permitted, the relatively small sample limited the ability to reliably adjust for the combined effects of these variables. In addition, the relatively large number of statistical comparisons increases the possibility of type I error; therefore, the reported associations should be interpreted with appropriate caution despite the use of adjusted p-values for multiple comparisons. The lack of a separate untreated control group also limits causal interpretation of the changes observed after equipment and training modifications. Therefore, the observed associations should be interpreted with caution and not considered independent effects of individual factors. Further studies with larger and more homogeneous samples and multivariate analysis adjusted for age, breed, sex, discipline, and previous injury are needed to confirm these findings. Thus, the findings are consistent with the broader development of veterinary biomechanics from conventional clinical assessment toward quantitative, multimodal monitoring. The monitoring and analysis technologies discussed in the present study may improve the objectivity of locomotion assessment and support more individualised approaches to training and rehabilitation. The observed relationships between movement asymmetry, stride characteristics, load distribution, and thermographic changes support further investigation of integrated monitoring as a complementary tool for early identification of biomechanical abnormalities. However, prospective controlled studies with larger samples are required to determine whether such monitoring can reduce injury incidence and improve long-term clinical outcomes.

## 5. Conclusions

The study determined that biomechanical motion analysis may be useful for early detection of musculoskeletal disorders in sport horses. The horses with subclinical lameness and post-traumatic conditions showed a reduction in stride length by 15±2% and an increase in stride frequency compared to clinically healthy individuals. The distribution of vertical reaction force shifted towards the front limbs in horses with chronic injuries, with 65±4% of body weight, indicating overload of the front limbs. The asymmetry coefficient in pathological groups exceeded 12-25% compared to ≤5% in healthy animals, therefore, this parameter may serve as a potential quantitative marker of hidden abnormalities. Thermographic examination revealed local areas of hyperthermia above 1.5°C, which correlated with clinical signs of pain and reduced range of motion. Inertial sensors recorded a decrease in the range of motion of the lumbar spine by 8.3±1.2° when an inappropriate equipment was used. The saddle adjustment and training-load optimisation were associated with improvements in biomechanical parameters; however, their preventive effectiveness cannot be established definitively without a controlled intervention design.

This study developed a prevention algorithm, consisting of regular assessment, early identification of abnormalities, individual correction, and subsequent monitoring, which has the potential to serve as a practical framework for preventive management in equestrian sports. Hence, further studies are required for validation of its effectiveness under controlled conditions. The results of this study support the feasibility of integrating biomechanical methods into the system of injury prevention and diagnosis in sport horses. A promising direction for further research is an in-depth analysis of the influence of type of horseshoe on the symmetry of movement, as well as the study of the long-term effects of shock absorption systems in the context of injury prevention. In addition, it is necessary to expand the use of wearable sensors for long-term monitoring, which will improve diagnostic accuracy and early detection of pathologies. Future controlled studies may also help determine whether these approaches can contribute to reducing injury incidence and improving individualised treatment and prevention programmes. However, the observations of this study should be interpreted as preliminary and require confirmation in larger, adequately powered studies with pre-specified multivariable analyses, appropriate correction for multiple comparisons, and long-term monitoring of biomechanical changes.

## Declarations

**Funding**: Not applicable

**Conflict of interest**: The author declare no conflicts of interest

**Acknowledgements**: None

**Ethics approval:** Described in the Materials & Methods section

## References

Aharkova K, Sliusarenko D, Novytskyi V. (2023). Analysis of the prevalence of osteoarticular pathologies in horses based on the results of radiography. Scientific Bulletin of Veterinary Medicine 1(180): 133-141. https://doi.org/10.33245/2310-4902-2023-180-1-133-141

Anderson K, Morrice-West AV, Walmsley EA, Fisher AD, Whitton RC, Hitchens PL. (2022). Validation of inertial measurement units to detect and predict horse behaviour while stabled. Equine Veterinary Journal 55(6): 1128–1138. https://doi.org/10.1111/evj.13909

Calle-González N, Lo Feudo CM, Ferrucci F, Requena F, Stucchi L, Muñoz A. (2024). Objective assessment of equine locomotor symmetry using an inertial sensor system and artificial intelligence: A comparative study. Animals 14(6): 921. https://doi.org/10.3390/ani14060921

de Camargo Ferraz G. (2023). The next decade for sport horses will be the time of wearable technology: Wearable technology for sport horses. International Journal of Equine Science 2(2): 1–2. https://doi.org/10.64292/ijes.90

de Sousa NR, Luna SPL, Pizzigatti D, Martins MTA, Possebon FS, Aguiar ACS. (2017). Relationship between type and location of orthopaedic injuries and physical activity in horses. Ciencia Rural 47(2): e20151218. https://doi.org/10.1590/0103-8478cr20151218

de Souza AF, do Valle Zoppa AL. (2021). Proximal interphalangeal joint arthrodesis in horses: concepts, indications, and techniques. Brazilian Journal of Veterinary Research and Animal Science 58: e178586. https://doi.org/10.11606/issn.1678-4456.bjvras.2021.178588

Dittmann MT, Hess N, Arpagaus S, Müller-Quirin J, Weishaupt MA, Latif SN. (2022). Effects of different saddle pads on pressure exerted on the equine back by correctly fitting dressage saddles. Pferdeheilkunde 38(2): 100–108. https://doi.org/10.21836/pem20220201

Dörner CA. (2023). Locomotor injury morbidity data analysis in Chilean sport horses: A retrospective study (2016–2021). Austral Journal of Veterinary Sciences 55(2): 137–141. https://doi.org/10.4067/S0719-81322023000200137

European Convention for the Protection of Vertebrate Animals used for Experimental and other Scientific Purposes (ETS No. 123). (1986). https://www.coe.int/en/web/conventions/full-list?module=treaty-detail&treatynum=123

European Parliament and the Council. (2010). On the Protection of Animals used for Scientific Purposes Text with EEA Relevance (Directive No. 2010/63/EU). https://eur-lex.europa.eu/eli/dir/2010/63/oj/eng

Gmel AI, Haraldsdóttir EH, Serra-Bragança F, Lamas LP, Rosa TV, Stefaniuk-Szmukier M, Klecel W, Neuditchko M, Weishaupt MA. (2024). Inertial sensor data of horses from four breeds at walk and trot in hand on a straight line. Data in Brief 55: 110764. https://doi.org/10.1016/j.dib.2024.110764

Hagen J, Jung FT, Brouwer J, Bos R. (2021). Detection of equine hoof motion using a hoof-mounted inertial measurement unit sensor compared with optoelectronic technique – A pilot study. Journal of Equine Veterinary Science 101: 103454. https://doi.org/10.1016/j.jevs.2021.103454

Hitchens PL, Whitton C. (2024). Epidemiology of orthopaedic injury and death in athletic horses. In: Hinchcliff KW, Kaneps AJ, Geor RJ, editors, Equine Sports Medicine and Surgery: Basic and Clinical Sciences of the Equine Athlete. W.B. Saunders, Pennsylvania, USA. Pp. 220–232. https://doi.org/10.1016/B978-0-7020-8370-9.00011-4

Hoffmann MF, Bernstorff M, Kreitz N, Roetman B, Schildhauer TA, Wenning KE. (2023). Horse-related injury patterns: A single center report. Journal of Orthopaedic Surgery and Research 18: 83. https://doi.org/10.1186/s13018-023-03549-3

Jaafar SE, Al-Bayti AAH, Abdullah SI. (2021). Using short-term high-power laser therapy in horse tendon injuries. Archives of Razi Institute 76(5): 1437–1444. https://doi.org/10.22092/ari.2021.356105.1779

Kulynych S, Kramarenko V, Zezekalo M, Omelchenko A, Avramenko N. (2022). Efficiency of orthopedic cleaning of horses' hooves. Scientific Progress & Innovations 2(2): 223–231. https://doi.org/10.31210/visnyk2022.02.26

Kulynych SM, Omelchenko GO, Avramenko NO, Zezekalo MA, Karpenko IO. (2020). Studying the state of horse distal limb segment in the horse club "Astride Riding in Poltava". Scientific Progress & Innovations 4: 210–217. https://doi.org/10.31210/visnyk2020.04.26

MacKechnie-Guire R, Fisher M, Mathie H, Kuczynska K, Fairfax V, Fisher D, Pfau T. (2021). A systematic approach to comparing thermal activity of the thoracic region and saddle pressure distribution beneath the saddle in non-lame sport horses. Animals 11(4): 1105. https://doi.org/10.3390/ani11041105

Mostafa MB, Elemmawy YM. (2020). Relationships between morphometric measurements and musculoskeletal disorders in jumping Thoroughbred horses. Journal of Equine Science 31(2): 23–27. https://doi.org/10.1294/jes.31.23

Neville EK, Hicks H, Neville CC. (2024). Epidemiology of horse trauma: A literature review. European Journal of Trauma and Emergency Surgery 50(3): 741–754. https://doi.org/10.1007/s00068-023-02436-0

Ortved KF. (2018). Regenerative medicine and rehabilitation for tendinous and ligamentous injuries in sport horses. Veterinary Clinics of North America: Equine Practice 34(2): 359–373. https://doi.org/10.1016/j.cveq.2018.04.012

Paris A, Beccati F, Pepe M. (2021). Type, prevalence, and risk factors for the development of orthopaedic injuries in endurance horses during training and competition. Journal of the American Veterinary Medical Association 258(10): 1109–1118. https://doi.org/10.2460/javma.258.10.1109

Ramon T, Álvarez CBG, Carmona JU, Prades M. (2025). Effect of a single osteopathic manipulation of dysfunctional caudal cervical vertebrae in non-lame sport horses. Journal of Equine Rehabilitation 3: 100037. https://doi.org/10.1016/j.eqre.2025.100037

Reis IL, Lopes B, Sousa P, Sousa AC, Caseiro AR, Mendonça CM, Santos JM, Atayde LM, Alvites RD, Maurício AC. (2024). Equine musculoskeletal pathologies: clinical approaches and therapeutical perspectives – A review. Veterinary Sciences 11(5): 190. https://doi.org/10.3390/vetsci11050190

Šemrov MZ, Přibylová L, Gobbo E. (2025). Task-specific morphological and kinematic differences in Lipizzan horses. Frontiers in Veterinary Science 12: 1569067. https://doi.org/10.3389/fvets.2025.1569067

Shojaee A. (2023). Equine tendon mechanical behaviour: Prospects for repair and regeneration applications. Veterinary Medicine and Science 9(5): 2053–2069.

https://doi.org/10.1002/vms3.1205

Sweeney D, Holmström M, Donohue KD, Lambert DH, Bayly WM. (2024). Using accelerometers to identify a high risk of catastrophic musculoskeletal injury in three racing thoroughbreds. Journal of the American Veterinary Medical Association 262(9): 1242–1250. https://doi.org/10.2460/javma.24.02.0114

Watts AE. (2023). Use of stem cells for the treatment of musculoskeletal injuries in horses. Veterinary Clinics of North America: Equine Practice 39(3): 475–487. https://doi.org/10.1016/j.cveq.2023.07.003

Yildirim İG, Karaarslan S, Erkan A. (2025). Distribution of race- and training-related musculoskeletal injuries by track and location in thoroughbred and arabian racehorses. Equine Veterinary Journal 57(4): 878–888. https://doi.org/10.1111/evj.14457

Zetterberg E, Persson-Sjodin E, Lundblad J, Hernlund E, Rhodin M (2024). Prevalence of movement asymmetries in high-performing riding horses perceived as free from lameness and riders' perception of horse sidedness. PLOS One 19(7): e0308061. https://doi.org/10.1371/journal.pone.0308061

**Citation**

Martynova O. (2026). Biomechanics of the locomotor system in sport horses: Diagnosis of disorders and injury prevention. Letters in Animal Biology 06(1): 118 – 129. *https://doi.org/10.62310/liab.v6i1.390*