Pilot Study on the Development and Assessment of a Novel Sensor for Measuring Rein Tension

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Pilotstudie zur Entwicklung und Bewertung eines neuartigen Sensors zur Messung der Zügelspannung

Eine effektive Kommunikation zwischen Pferd und Reiter ist im Pferdesport sowohl für die Leistung als auch für das Wohlergehen des Tieres von entscheidender Bedeutung. Die Zügelspannung, die häufig durch negative Verstärkung (d. h. das Lösen des Drucks als Belohnung für eine gewünschte Reaktion) eingesetzt wird, spielt in dieser Interaktion eine zentrale Rolle. Eine zu hohe oder ungleichmässige Spannung kann jedoch insbesondere im Maulbereich zu Beschwerden oder Verletzungen führen. Während frühere Studien die Zügelspannung bei Grundgangarten wie Schritt, Trab und Galopp analysiert haben, gibt es nur wenige Untersuchungen zu komplexeren Manövern wie Springen oder abrupten Stopps. Diese Pilotstudie stellt ein speziell entwickeltes, auf Dehnungsmessstreifen basierendes Sensorsystem vor, das zur Messung der Zügelkraft unter typischen Reitbedingungen konzipiert wurde. Es wurde eine hohe Abtastrate konfiguriert, um kurzzeitige Spannungsspitzen genau erfassen zu können. Die Sensoren wurden kalibriert und wiesen eine Genauigkeit von < 1 % auf. Fünf professionelle Reiter-Pferd-Teams absolvierten standardisierte Einheiten, die verschiedene Gangarten, Sprünge und unerwartete Stopps umfassten. Die statistische Analyse ergab signifikante Unterschiede in der Zügelspannung zwischen den verschiedenen Gangarten ($p < 0{,}05$). Die mittleren Zügelkraftwerte betrugen 16,7 N im Schritt, 29,7 N im Trab, 36,8 N im Galopp, 114,2 N beim Springen und 200,3 N bei unerwarteten Stopps. Die Sensoren funktionierten während des gesamten Tests zuverlässig und konsistent und beeinträchtigten die Reitleistung nicht. Die Zügelzugkraftmuster wurden sowohl von der Art des Manövers als auch von der individuellen Dynamik zwischen Reiter und Pferd beeinflusst. Die Ergebnisse deuten darauf hin, dass das System für die Bewertung der Zügelzugkraft unter typischen Reitbedingungen zuverlässig ist.

Schlüsselwörter: Pferdesport, Interaktion zwischen Pferd und Reiter, Sensorkalibrierung, Signalanalyse, Dehnungsmessstreifen-Sensor, Zugkraftmessung

Abstract

Effective horse–rider communication is essential in equestrian sports, both for performance and animal welfare. Rein tension, which is often applied through negative reinforcement (i.e., the release of pressure to reward a desired response), plays a central role in this interaction. However, high or inconsistent tension can lead to discomfort or injury, particularly in the mouth cavity. While previous studies have analyzed rein tension in basic gaits such as walk, trot, and canter, limited research exists on more complex maneuvers like jumping or abrupt stops. This pilot study introduces a custom-designed strain gauge-based sensor system developed to measure rein tension under typical riding conditions. A high sampling rate was configured to allow accurate detection of short-duration tension peaks. The sensors were calibrated and showed an accuracy of < 1 %. Five professional rider–horse teams performed standardized sessions including various gaits, jumping, and unexpected stops. Statistical analysis showed significant differences in rein tension between gaits ($p < 0.05$). Mean rein tension values were 16.7 N for walking, 29.7 N for trotting, 36.8 N for canter, 114.2 N for jumping, and 200.3 N for unexpected stops. The sensors functioned reliably and consistently throughout testing and did not interfere with riding performance. Rein tension patterns were influenced by both the type of maneuver and individual rider–horse dynamics. The results suggest that the system is reliable for rein tension evaluation under typical riding conditions.

Keywords: equestrian sports, horse–rider interaction, sensor calibration, signal analysis, strain gauge sensor, tension measurement

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Introduction

Effective communication between rider and horse across various gaits and maneuvers is essential, not only for successful performance in equestrian sports, but also for the welfare of the horse.[5,16,24] The reins, acting through the bit, play a central role in this communication, following the idea of negative reinforcement from learning theory: where tension is applied to give a command and then released as a reward for correct responses.[1,6,39]

The fundamental gaits executed in a riding session are walk, trot, and canter, in clockwise (CW) and anticlockwise (ACW) directions, emphasizing the adaptability required in equestrian activities. Symmetry and equal performance in both directions are desired but rarely accomplished,[2] suggesting the value of further research for improving riding techniques.

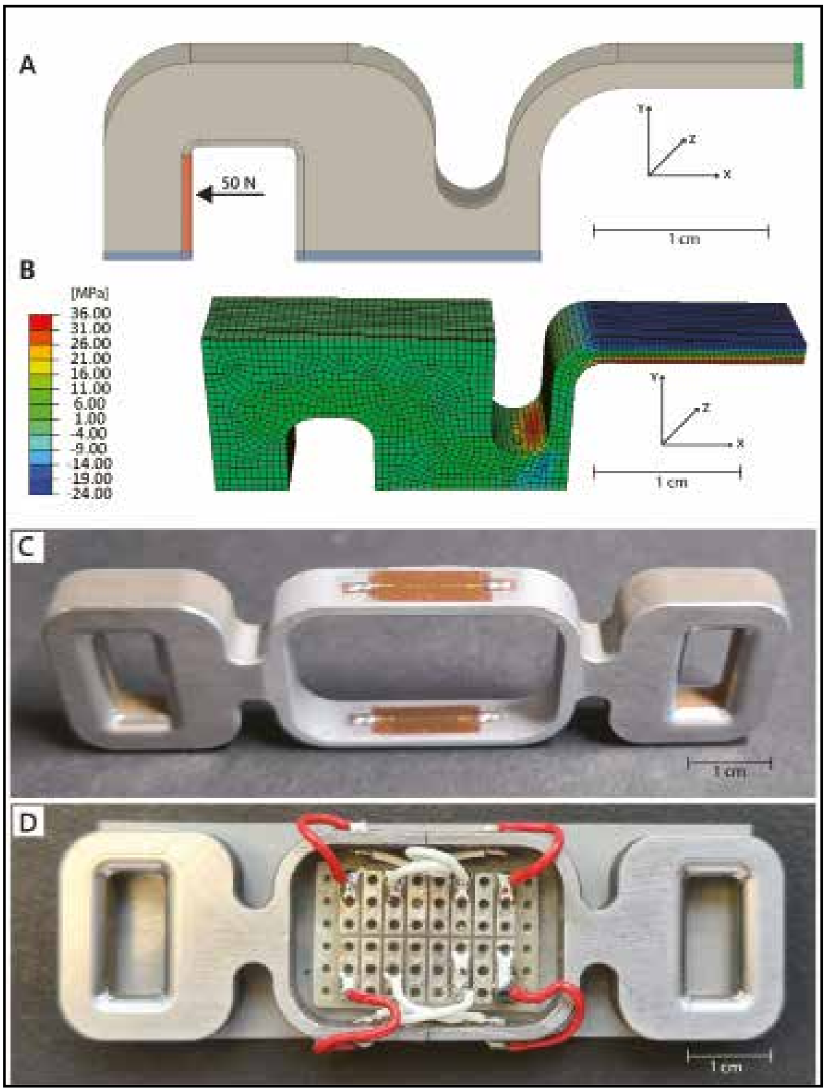

Figure 1: Sensor design. (A) shows the CAD quarter model with the colored areas where boundary conditions and loads were applied, (B) shows the FE quarter model for the sensor design (for a total load of 100 N in the full model) with stress distribution in x direction MPa, (C) shows the position of the strain gauges, and (D) the connection of strain gauges in a Wheatstone bridge configuration.

Oral lesions have been reported in ridden horses, with Uldahl and Clayton (2019) finding noticeable lesions or blood at the lip commissures in 9,2 % of 3,142 horses, with an increasing prevalence at higher competition levels.[35] Nevertheless, no differences were observed with respect to the type of bit or the use of bitless bridles.[35] Understanding rein forces is therefore crucial for ensuring horse welfare.[8]

Previous studies have explored rein tension across gaits, highlighting its modulation in response to varying speeds and locomotion patterns.[9] Rein tension magnitudes vary significantly between studies. Warren-Smith et al. (2007) reported mean values of 5.10 N for walking and 9.00 N for trotting.[37] Piccolo & Kienapfel (2019), reported magnitudes of 16.5 ± 10.2 N for walk, 23.2 ± 14.1 N for trot, and 35.9 ± 18.1 N for canter.[27] In Clayton et al. (2005), values in the range of 4 to 43 N for walk, 19 to 51 N for trot, and 21 to 104 N for canter were reported.[6] Variability in rein tension is influenced by different factors such as riding styles.[36] Horse sensitivity, and the experience of both rider and horse, underscoring the need for further research.[34,38]

Despite dressage riding, horses are frequently involved in disciplines such as show jumping, eventing, and western riding, which include fast maneuvers, unexpected turns, and sudden stops that remain understudied in rein tension research. Jumping requires coordination and balance, and the impulse generated at take-off and the impact upon landing may increase rein tension. Unexpected stops involve abrupt movements that can lead to sudden rein pulling, potentially increasing pressure on the jaw. Although unexpected stops are uncommon in equestrian sports, it is important to analyze their implications, as they may occur in unplanned situations.

In order to capture rein tension under typical riding conditions, a stiff customized strain gauge-based sensor system was developed. In contrast to spring-based systems, they have the advantage of behaving very rigidly and do not create any force feedback displacement, which may lead to instability.[38] The sensors (left and right) were internally configured as full Wheatstone bridges and calibrated from 0 to 500 N to ensure a complete measurement range. Signal amplification was integrated to ensure sufficient resolution, and a 1000 Hz sampling frequency was chosen. While some previous systems have been limited by low frequency, high weight, a restricted force range, or insufficient mechanical resistance,[4,8,10,20,25] our design prioritized accuracy and robustness to meet the demands on the field. The development of such instrumentation represents a valuable step forward in equitation science and contributes to a more objective assessment of rider–horse interactions.

In this pilot study the rein tension in horseback riding was explored across fundamental gaits as well as during jumping and unexpected stops, aiming to evaluate the performance of the developed sensor system under typical riding conditions and assess its suitability for capturing rein tension across a range of equestrian activities.

Materials and Methods

Ethical Approval

No ethical approval was necessary for the tests described, as they were conducted as part of the horse's routine exercise regimen. Informed consent was obtained from all horse owners prior to data collection. The study adhered to the Swiss Equestrian Federation's ethical principles for horse welfare.[31]

Sensor Development

To develop a reliable device, a dedicated sensor structure was designed and optimized. To assess its mechanical performance, a Finite Element (FE) analysis was conducted using Simulia Abaqus[7] to ensure an optimal strain distribution within the sensor struts. For the FE model, boundary conditions were defined. In Figures 1-A, the following can be observed: symmetry about plane X was defined for green surface and symmetry about Y axis was defined for the blue surface. A 2.08 MPa pressure was applied on the 24 mm^2 red surface, corresponding to a force of approximately 50 N. The material elastic modulus was defined as 210.000 MPa and Poisson's ratio as 0.3. Based on the simulation results (Figures 1-B), a symmetric, double-loop geometry was selected and implemented (Figures 1-B,C). The final strut thickness of 1,5 mm in the center part allows optimal measurable strain by the strain gauges. For safety reasons and to withstand high mechanical loads, the sensors were manufactured from high-yield strength steel (Toolox 44, yield strength: 1150 N/mm^2).

Strain gauge transducers are widely recognized for their high-precision accurate force measurement capabilities.[18] Therefore, four unidirectional 120 Ω strain gauges were used — two placed on the interior and two on the exterior side of the slender medium part of the design. The strain gauges generate a voltage signal that is proportional to the applied force on the sensor structure. The four gauges were connected in a full Wheatstone bridge configuration, which improves measurement accuracy and compensates for temperature differences (see Figures 1-B,C).[19]

The model resulted in a 62 g sensor. The sensors (left & right) were configured with a high sampling frequency of 1000 Hz to ensure no tension peaks were missed, enabling a detailed analysis.

In addition to the calibrated sensors, a 3,5 kg backpack containing the system equipment, including an amplifier, data logger, and battery, was carried by the riders, who reported that the equipment caused minimal interference with the riding practice.

The amplifier was connected to the battery, and the sensors were connected to the amplifier through cables. Figures 3-A shows the full setup for the experimental design, while Figures 3-B displays the individual system components. The

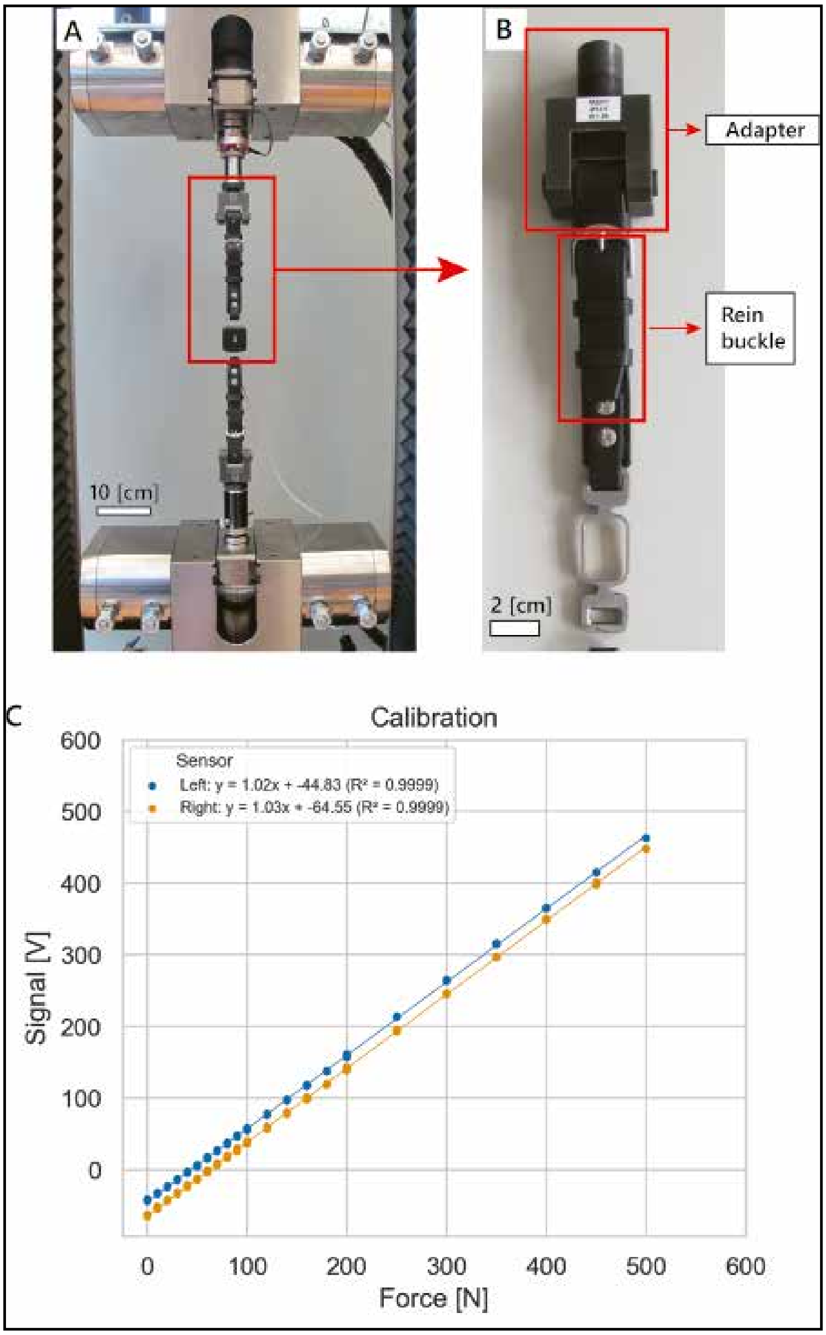

Figure 2: Calibration setup. (A) Tensile configuration in the Universal Testing Machine, with the sensor attached by the rein buckles and adapter to the machine, (B) shows a zoom of the region of interest showing the different parts. Labels and arrows show each component, and (C) shows the calibration data and linear regression for each sensor.

sensor's placement with the reins is illustrated in Figures 3-C.

For safety reasons, a detachable plug (a VGA-type connector) was integrated into the signal cable. This connector was designed to automatically disconnect in case the rider falls, thereby preventing damage to the electrical connections and enhancing safety for both the rider and the horse by avoiding entanglement or tension in the cables.

Sensors Calibration

An exhaustive calibration process up to 500 N was conducted to validate the sensors performance. Quasi-static tensile tests were performed in a Universal Testing Machine.[40] The calibration setup, including the sensors attached to the buckles via a fork adapter, is shown in Figures 2-A,B.

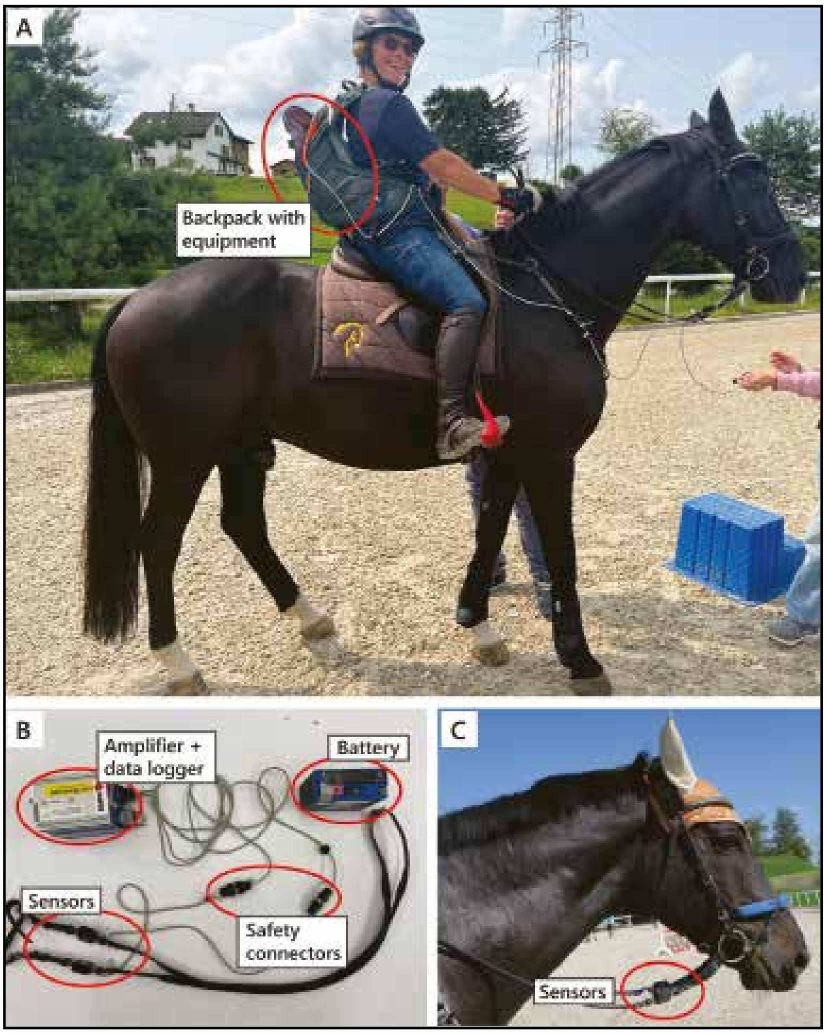

Figure 3: Measurement equipment and setup. (A) Shows the rider wearing the backpack containing the amplifier/data log-ger and the battery, in (B) the complete measurement equipment and (C) shows the two sensors attached to the reins (one on the left side and one on the right side of the horse neck).

Stepwise loading cycles were applied to cover a force range from 0 to 500 N. A 200 N load cell (class 0.5) was used for the lower range (0–200 N), while a 10 kN load cell (class 0.5) was used for higher loads (200–500 N). Smaller force increments were applied at lower loads, whereas larger increments were used at higher loads, reflecting the improved measurement accuracy in this range. Each step was applied at a constant loading rate and held briefly to allow signal stabilization, and the loading–unloading cycles were repeated three times.

At each step, the corresponding voltage output of the sensors was recorded for further analysis and calibration results are depicted in Figures 2-C. The results showed an excellent linear correlation between applied force and sensors output, with a Root Mean Square Error (RMSE) of 1.51 N for the left rein sensor and RMSE = 1.60 N for the right rein sensor (Figures 2-C), corresponding to an accuracy of ± 0,6 % over the 500 N range (estimated as $\frac{2 \cdot RMSE}{500\,N}$ for a 95 % confidence level).

Rein Adaptation for Sensor Attachment

Standard rubber reins were specifically modified for the purpose of this study by separating them into two parts. Each rein segment was equipped with a buckle on both sides of the sensor's eyelet to facilitate attachment, thereby keeping the distance from the single-jointed snaffle bit as short as allowed by the buckle configuration (10 cm). This ensured that the sensors were mounted in the same manner on both sides. This design choice aligns with the methodology described by Eisersiö et al. (2015). [13]

Analysis of Horses

The selected horses regularly take part in dressage, show jumping or competitions events and have been regularly examined by veterinarians regarding their health. These horses were healthy at the time of this study as well as in the two previous months and did not receive any medication. Before the measurements were taken, all horses were examined orthopedically, and no lameness or other abnormal findings were found. The oral cavity was also examined in detail and no abnormalities of the teeth or other structures in the mouth could be recognized.

Riding Protocol

The riding protocol consisted of five teams composed of a rider and a horse performing the same riding session. Three professional riders with five experienced horses participated in the rein tension test (Tables 1, 2 and 3). All riders were professional equestrians who had successfully completed three to five years of formal riding education. Their experience includes participation in sporting competitions, primarily dressage, with less frequent involvement in show jumping and cross-country. Each rider only rode the horses they are used to train with to ensure familiarity.

Prior to the riding session, the horses underwent a warmup that included walking, trotting, and cantering in right and left directions, defined in this study as CW and ACW directions respectively. After the warmup, riders were equipped with the sensor system and followed the provided standardized instructions for the study. The horses were ridden with a normal water snaffle, and the head or nose was set in front of the vertical.

Three gaits were evaluated in both CW and ACW directions, following a protocol similar to that described by E. Hartmann et al,[16] in an outdoor riding arena (20×55 m^2) with a base of quartz and silicon sand mixed with various fibers and textiles. Each gait was executed in good contact (short reins), first in an ACW direction, followed by a CW direction. Similar riding times were ensured for each gait by varying the number of laps: one lap for walk, two laps for trot, and three laps for canter were executed sequentially, each followed by a 10-second pause. Figures 4 summarizes the riding protocol. Riders were instructed to maintain their usual riding habits without altering their handling of the reins, as in E. Hartmann et al.[16]

Three teams were selected to perform a circuit of three jumps, each with a height of 70 cm. Moreover, two riders were asked to perform an unexpected stop for the horse while canter. To perform the unexpected stop, the riders were asked to ride normally and stop suddenly when instructed by the supervisor.

The handedness of the riders and laterality of the horses was declared by each rider at the beginning of the study.

The horse laterality refers to the preference for using one side of the body for movement, it can be defined due to body asymmetry (anatomical differences in the left and right side of the body), motor laterality (tendency to favor the limbs on one side of the body), and sensory laterality (bias toward using sensory input from one side of the body, e.g. eyes, ears).[21] This was determined by the riders based on subjective characteristics: easier canter to the dominant side,[15] preference of legs position when eating (dominant leg is positioned in the front).[2, 22]

Table 1: Information about the riders. Each rider has an identification letter. Gender, age, years of experience and dominant hand are reported.

Rider				
ID	Gender	Age (years)	Experience (years)	Handedness
A	Female	33	20	Left
B	Female	59	45	Right
C	Female	35	20	Right

Table 2: Information about the horses. Each horse has an identification number. Sex, age, years of training and sidedness are reported.

Horse				
ID	Sex	Age (years)	Training (years)	Laterality
I	Female	16	13	Left
II	Male	12	9	Left
III	Female	14	11	Right
IV	Male	7	4	Left
V	Male	13	10	Left

Table 3: All the five evaluated combinations between riders and horses were identified as a team.

Teams		
ID	Rider	Horse
Team 1	A	I
Team 2	B	II
Team 3	A	III
Team 4	B	IV
Team 5	C	V

Data Management

The acquired data were later processed and the highest force values for each step (so-called force peaks) were recorded as performed in.[11] Data segmentation between actions was performed using LMS Tecware.[33] Subsequently, signal refinement and analysis was carried out using a custom-made Python script.[38] The high acquisition frequency of 1000 Hz ensured that critical features, such as peaks, were accurately captured, enhancing temporal resolution. However, it also resulted in a higher level of noise in the recorded signal. 'Noise' refers to rapid, low-amplitude signal fluctuations caused by motion artifacts of the reins. The script reduces the noise of the signal for data analysis purposes using a «moving_average» function

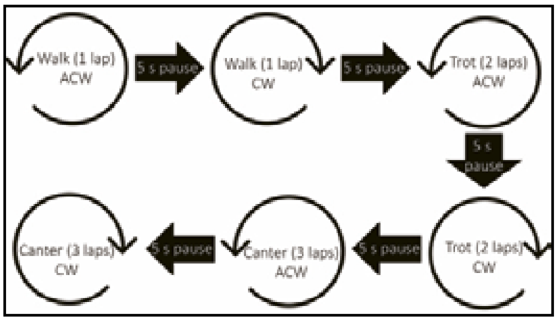

Figure 4: Diagram of the riding protocol showing the gaits, directions, and number of laps. CW = Clockwise direction and ACW = Anticlockwise direction.

and identify the peaks of each horse step (Figures 5),[5] using a «find_peaks» function from the scipy.signal Python toolbox.[32] This procedure gives peak values on average 5 % lower than the original data. The load value and time of each identified peak was saved and exported for further analysis.

Data Analysis and Statistics

Statistical evaluations of the measured data were done using «R» software (Version 4.5.1)[30] in the RStudio environment (Version 2025.05.1).[28]

The normality of the data was assessed prior to statistical analysis, and parametric methods were considered appropriate. In a pre-analysis the effect of the direction (CW versus ACW) and the side of the measurements (left rein versus right rein tension) were analyzed with a Linear Mixed Model (LMM) implemented via the lmerTest package in R software[23] with «Team» (consisting of a rider and a horse) as the random variable and «Gait», «Direction» and «Side» (rein side) as categorial factors. Based on the outcome, the direction is not influencing the tension, this factor was omitted in the final analysis. However, the rein side effects were very significant ($p < 0,05$). Therefore, the measurements were split into two independent observations: rein tension on the left side and rein tension on the right side. In the final analysis, the five teams were treated as subjects, each completing the same sequence of laps as given in Figures 4. Therefore, the data gained during various gaits were treated as repeated measures. For each side, the measurements for walking, trotting and canter were analyzed separately in a Linear Mixed Model (LMM), with «Team» as the random variable and «Gait» as the categorial factor. For jumping and unexpected stopping paired t-tests were done.

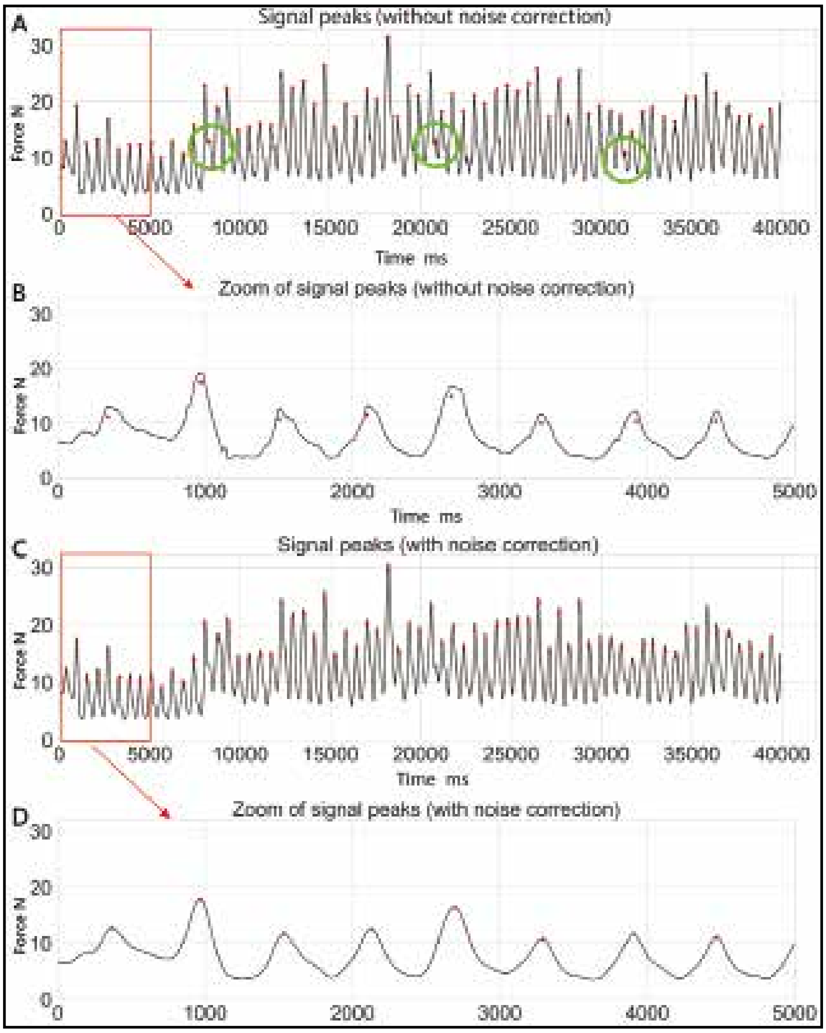

Figure 5: Rein tension signal for team 2 in walking CW, left rein. The highlighted points represent the identified force peaks. (A) Signal without noise correction (when the noise is not corrected, some signal irregularities, such as little peaks, are not removed, see green circles), (B) Zoom of chart a, showing the peaks of eight horse steps in five seconds, (C) Same signal as in chart a with noise correction, (D) Zoom of chart c.

Results

Descriptive Statistics:

The results for each gait are summarized in Table 4, where the present data are compared with values reported in the literature. The corresponding data distributions for walk, trot, and canter are shown in Figures 6, while Figures 7 & 8 present the measurements for the left and right rein, respectively.

Statistical Testing:

Walking, trotting, and canter show significantly different rein tension on each side, left as well as right ($p < 0,05$). Jumping shows higher tension compared to canter for team 2, team 3 and team 5 ($p < 0,05$). A difference between jumping and unexpected stopping could not be found based on measurements gained with team 3.

Figure 9-A presents a comparison of the different teams for each gait and rein side highlighting the distinct variations among the teams. The results associated with each team reveal considerable variability in observed variables; it can be particularly interesting when the same rider is mounted on different horses. This variability is illustrated in the spider charts in Figures 9-B,C, which demonstrates the significant influence of the horse on rein tension. This observation aligns with the findings of Christensen JW (2021).[3]

Discussion

The main part of this study is the development of a novel rein tension sensor, which provided precise and reproduceable measurement values due to its robust design with optimal fit in the reins and high resolution. The device functioned reliably throughout all trials, showing stable readings with no signal loss or technical failures during dynamic maneuvers. The calibration confirmed a linear and consistent response across the measured force range, supporting its suitability for outdoor biomechanical analysis. Additionally, the 1000 Hz sampling rate exceeded the minimum requirement for detecting rapid tension changes, ensuring no relevant loss of information. While the system showed good performance, some limitations were noted, such as potential sensitivity to rein vibration and the relatively bulky nature of the complete system (sensors and backpack). Riders reported that although the system was not interfering with the ride performance, it was uncomfortable to wear. Nevertheless, the successful implementation of this system under typical riding conditions represents a promising step toward more objective monitoring of horse–rider interactions.

In the context of previously reported rein tension measurement systems, the present design incorporates several features that may facilitate reliable data acquisition under practical riding conditions. The sensors operates within a force range of 0–500 N, which is consistent with values reported in equestrian studies,[12,14,27] while exceeding the measurement limits of some previously described systems that were restricted to lower force ranges.[3,10] The calibration procedure, performed using a universal testing machine, ensured a linear and reproducible response, whereas other studies have relied on calibration using static weights, which may introduce additional uncertainties.[3,17] The high sampling frequency of 1000 Hz allows the detection of rapid force fluctuations, in contrast to lower acquisition rates reported in earlier studies,[11,13] which may not fully capture transient events.

In addition, the mechanical design, based on a robust steel structure, enhances durability and safety during dynamic loading scenarios, particularly in comparison to systems where structural limitations or failures have been reported.[20] Furthermore, although wearable rein tension devices have previously been described as relatively bulky or interfering with riding performance,[5,6] the present system caused only a certain level of discomfort, mainly associated with the backpack used for data acquisition, and did not affect rein handling.

Table 4: Comparison of rein tension values across gaits between previous studies and the present study. Data are presented in the original format reported by each study (mean, mean ± SD, or min – max range).

Gait	Warren-Smith et al. (2007)[37]	Piccolo & Kienapfel (2019)[27]	Clayton et al. (2005)[6]	Current Study (2026)*
	Mean [N]	Mean ± SDEV [N]	Min – Max [N]	Mean ± SDEV [N]
Walk	5.10	16.5 ± 10.2	4 – 43	16.7 ± 8.8
Trot	9.00	23.2 ± 14.1	9 – 51	29.7 ± 14.6
Canter	–	35.9 ± 18.1	21 – 104	36.8 ± 21.7
Jump	–	–	–	114.2 ± 24.7
Unexpected Stop	–	–	–	200.3 ± 94.9

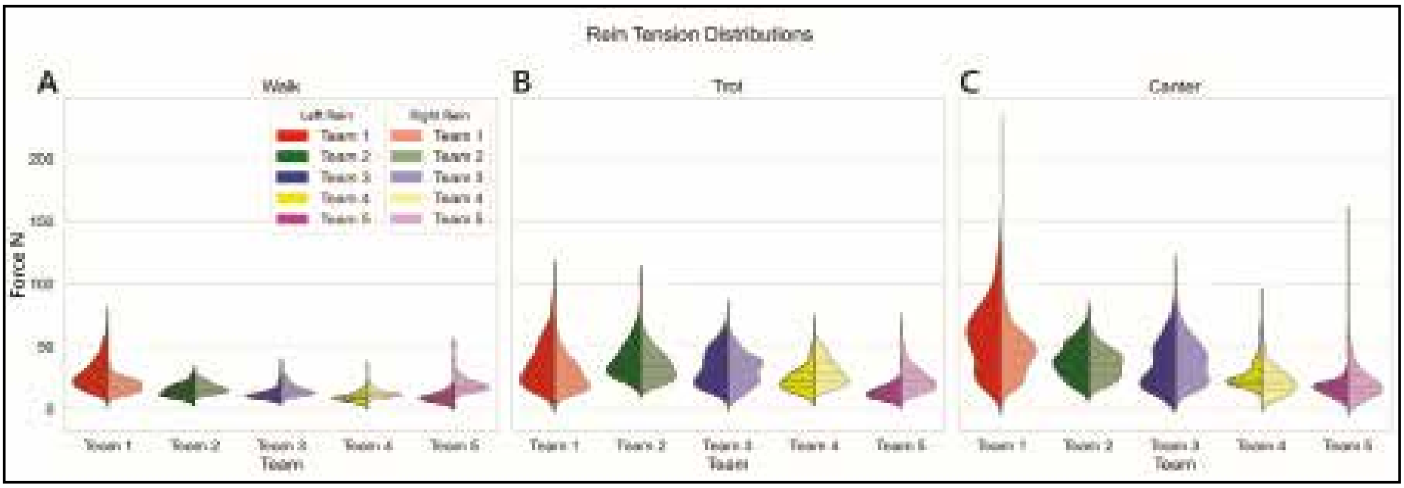

Figure 6: Peak rein tension measured values for each gait and team. (A) For walk, (B) for trot, and (C) for canter.

While the number of horses and riders in this study is limited, the observed variations in rein tension across different teams demonstrated that individual factors may influence communication dynamics. This study's findings align with previous research,[27] emphasize the importance of rein tension modulation across gaits. The robust sensor system used in this research revealed the varying magnitudes of rein tension during walk, trot, and canter, without significant differences between CW and ACW directions. During walking lower tension peak values were observed, during trot intermediate peak loads, and during canter higher peak loads. These results suggest a potential link between gait, speed and increased tension, following the same pattern as,[6,27,37] nevertheless the loads obtained in this study are in general higher than in the mentioned studies, reinforcing the influence not only of the gait, but also the peculiarity of horses and riders.

It is also worth noting that when the same rider rode different horses, notable differences in rein tension were observed, highlighting again the influence of the individual horse on rein tension dynamics. Additionally, the asymmetry in rein tension between the left and right reins did not appear to be associated with the rider's handedness or the horse's laterality.

The study included rein tension dynamics during jumping and unexpected stops. More data needs to be collected, including changing «teams» in order to explore distinct challenges and communication requirements with these activities The higher tension observed in these maneuvers highlight the distinct challenges and communication requirements associated with these activities. Rein tension values during jumping and unexpected stopping were notably higher than those observed during the fundamental gaits.

Limitations

In this study, riders exclusively rode their own regularly trained horses, limiting the diversity of interactions. To en-

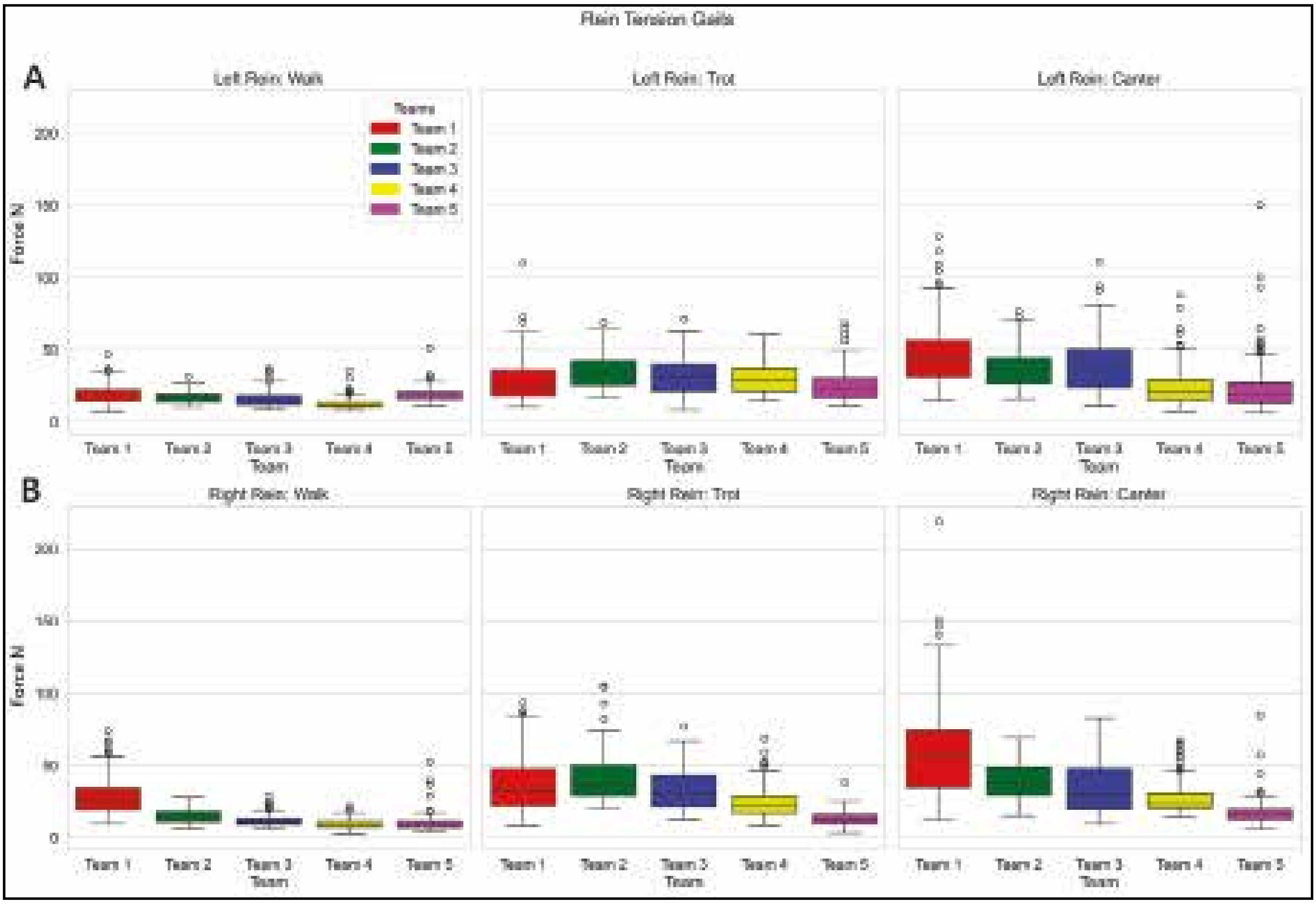

Figure 7: Rein tension peak values distribution for team, rein side and gait. (A) Left rein and (B) right rein.

hance the correlation between rider and horse performance, future research should incorporate a larger spectrum of teams. Furthermore, subsequent studies should consider comparisons with existing systems to further support and validate the observed reliability and overall performance of the developed sensor system.

Moreover, efforts in future research will target the downsizing of the sensor system to reduce its practical interference. Although the system was perceived as bulky and somewhat uncomfortable by the riders, none reported that it interfered with their riding performance. Nevertheless, this factor may significantly affect riders with less experience, as well as the execution of more physically demanding maneuvers. Therefore, reducing the size of the sensor system and using a wireless sensor system will be imperative for future research aiming to explore a wider range of equestrian contexts and participant skill levels.

Conclusion

This study explores the use of a rein tension novel sensor across different gaits and maneuvers using a novel sensor, experimentally tested under typical riding conditions. The sensor system was able to identify significant differences in forces between walking, trotting, and canter. Jumping take-off and landing, along with unexpected stops revealed higher loads. The findings suggest that the developed sensor is a reliable tool for measuring rein tension under the tested conditions, highlighting its potential for future research and broader implementation.

Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as potential conflict of interest.

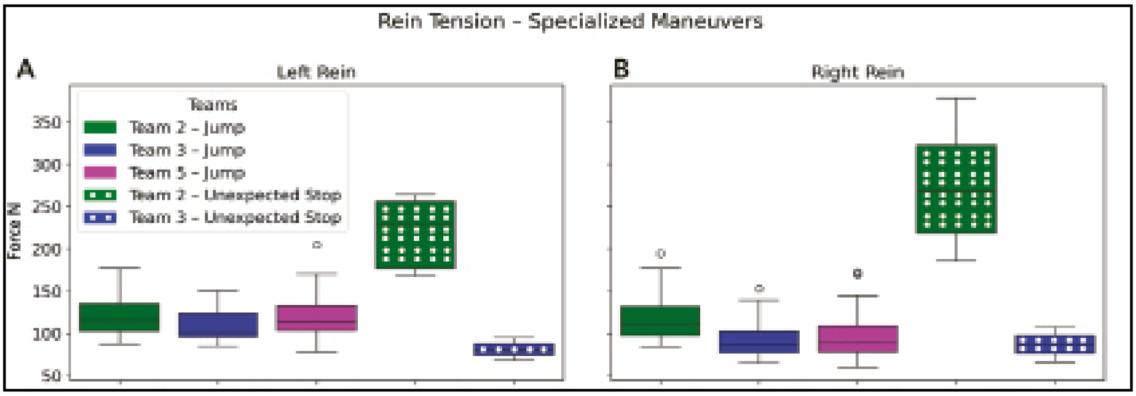

Figure 8: Peak rein tension measured values for jumping (teams 2, 3 and 5) and unexpected stop (team 3). (A) Left rein and (B) right rein.

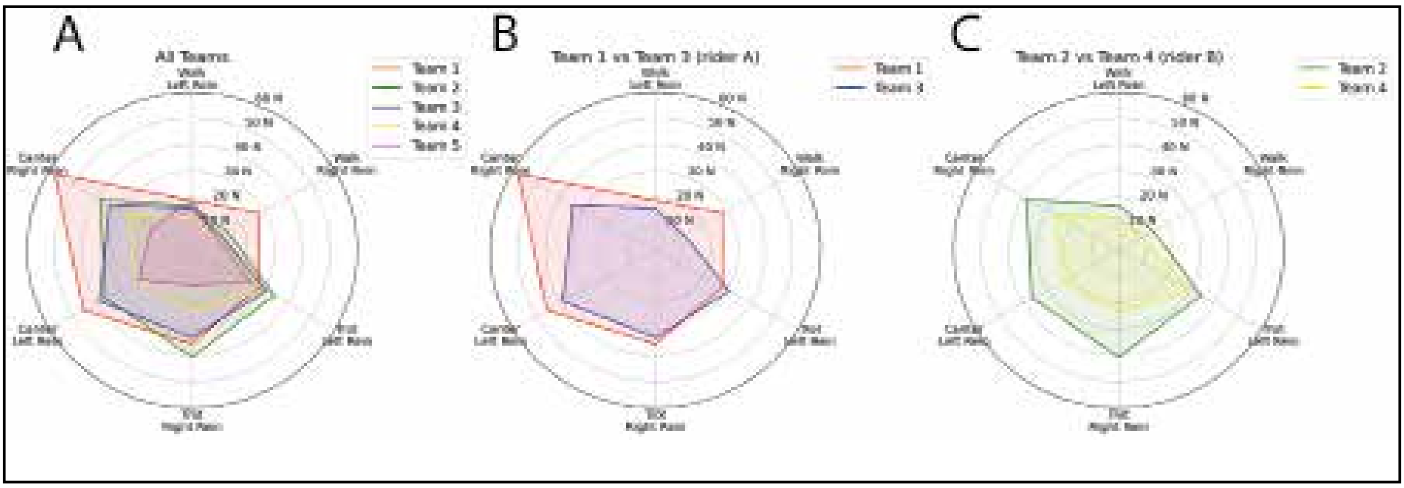

Figure 9: Average peak values of rein tension per gait for each team. (A) Average of peak values for all the teams, (B) values for teams 1 and 3, both teams with rider A (see details in Table 3), (C) average of peak values for teams 2 and 4, both teams with rider B (see details in Table 3).

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Declaration of generative AI and AI-assisted technologies in the writing process

For the preparation of this work, the authors used ChatGPT[26] for editing, grammar revision, and coding support purposes. After utilizing this tool, the authors reviewed the content. They take full responsibility for the correctness of the formulation and code implementation.

Étude pilote sur le développement et l'évaluation d'un nouveau capteur destiné à mesurer la tension des rênes

Une communication efficace entre le cheval et le cavalier est essentielle dans les sports équestres, tant pour la performance que pour le bien-être animal. La tension des rênes, souvent appliquée par le biais du renforcement négatif (c'est-à-dire le relâchement de la pression pour récompenser une réponse souhaitée), joue un rôle central dans cette interaction. Cependant, une tension trop forte ou irrégulière peut entraîner une gêne ou des blessures, en particulier au niveau de la cavité buccale. Alors que des études antérieures ont analysé la tension des rênes lors d'allures de base telles que le pas, le trot et le galop, peu de recherches existent sur des manœuvres plus complexes comme le saut ou les arrêts brusques. Cette étude pilote présente un système de capteurs spécial, basé sur des jauges de contrainte, développé pour mesurer la tension des rênes dans des conditions d'équitation particulières. Une fréquence d'échantillonnage élevée a été configurée pour permettre une détection précise des pics de tension de courte durée. Les capteurs ont été étalonnés et ont montré une précision de < 1 %. Cinq binômes cavalier-cheval professionnels ont effectué des séances standardisées comprenant diverses allures, des sauts et des arrêts inattendus. L'analyse statistique a montré des différences significatives de tension des rênes entre les allures (p < 0,05). Les valeurs moyennes de tension des rênes étaient de 16,7 N pour le pas, 29,7 N pour le trot, 36,8 N pour le galop, 114,2 N pour le saut et 200,3 N pour les arrêts inattendus. Les capteurs ont fonctionné de manière fiable et constante tout au long des essais et n'ont pas interféré avec les performances équestres. Les profils de tension des rênes ont été influencés à la fois par le type de manœuvre et par la dynamique individuelle cavalier-cheval. Les résultats suggèrent que le système est fiable pour l'évaluation de la tension des rênes dans des conditions d'équitation spécifiques.

Mots clés: sports équestres, interaction cheval-cavalier, étalonnage des capteurs, analyse des signaux, capteur à jauge de contrainte, mesure de la tension

Studio pilota sullo sviluppo e la valutazione di un nuovo sensore per la misurazione della tensione delle redini

Una comunicazione efficace tra cavallo e cavaliere è fondamentale negli sport equestri, sia per la performance sia per il benessere dell'animale. La tensione delle redini, spesso applicata attraverso il rinforzo negativo (ovvero il rilascio della pressione come ricompensa per una risposta desiderata), svolge un ruolo centrale in questa interazione. Tuttavia, una tensione elevata o incoerente può causare disagio o lesioni, in particolare nella cavità orale del cavallo. Sebbene studi precedenti abbiano analizzato la tensione delle redini nelle andature di base come passo, trotto e galoppo, esistono poche ricerche su manovre più complesse come il salto o le fermate improvvise. Questo studio pilota presenta un sistema di sensori personalizzato basato su estensimetri, sviluppato per misurare la tensione delle redini in condizioni tipiche di equitazione. È stata configurata un'elevata frequenza di campionamento per consentire il rilevamento accurato di picchi di tensione di breve durata. I sensori sono stati calibrati e hanno mostrato una precisione inferiore all'1 %. Cinque binomi professionali cavallo–cavaliere hanno eseguito sessioni standardizzate comprendenti diverse andature, salti e arresti improvvisi. L'analisi statistica ha evidenziato differenze significative nella tensione delle redini tra le diverse andature (p < 0,05). I valori medi di tensione delle redini sono stati: 16,7 N durante il passo, 29,7 N durante il trotto, 36,8 N durante il galoppo, 114,2 N durante il salto e 200,3 N durante gli arresti improvvisi. I sensori hanno funzionato in modo affidabile e costante durante tutte le prove e non hanno interferito con le prestazioni di guida. I modelli di tensione delle redini sono risultati influenzati sia dal tipo di manovra sia dalle dinamiche individuali di ciascun binomio. I risultati suggeriscono che il sistema è affidabile per la valutazione della tensione delle redini in condizioni tipiche di equitazione.

Parole chiave: sport equestri, interazione cavallo–cavaliere, calibrazione dei sensori, analisi del segnale, sensore a estensimetro, misurazione della tensione

Literaturnachweis

1 Brown SM, Connor M: Understanding and application of learning theory in UK-based equestrians. Anthrozoos 2017: 30(4): 565–579. DOI 10.1080/08927936.2017.1370216.

2 Byström A, Clayton HM, Hernlund E, Rhodin M, Egenvall A: Equestrian and biomechanical perspectives on laterality in the horse. Comp Exerc Physiol 2020: 16(1): 35–45. DOI 10.3920/CEP190022.

3 Christensen JW, Ahrendt LP, Lintrup R, Malmkvist J: Rider effects on horses' conflict behaviour, rein tension, physiological measures and rideability scores. Appl Anim Behav Sci 2021: 236: 105184. DOI 10.1016/j.applanim.2020.105184.

4 Christensen JW, Beekmans M, van Dalum M, van Dierendonck M: Effects of hyperflexion on acute stress responses in ridden dressage horses. Physiol Behav 2014: 128: 39–45. DOI 10.1016/j.physbeh.2014.01.024.

5 Clayton H, Mackechnie-Guire R, Byström A, Le Jeune S, Egenvall A: Guidelines for the measurement of rein tension in equestrian sport. Animals 2021: 11(10). DOI 10.3390/ani11102875.

6 Clayton HM, Singleton WH, Lanovaz JL, Cloud GL: Strain gauge measurement of rein tension during riding: a pilot study. Equine Comp Exerc Physiol 2005: 2(3): 203–205. DOI 10.1079/ecp200553.

7 Dassault Systèmes: Simulia Abaqus. Vélizy-Villacoublay, France, 2021. Available: www.3ds.com/products-services/simulia.

8 Dumbell L, Lemon C, Williams J: A systematic literature review to evaluate the tools and methods used to measure rein tension. J Vet Behav 2019: 31: 82–91. DOI 10.1016/j.jveb.2018.04.003.

9 Egenvall A, Byström A, Roepstorff L, Rhodin M, Eisersiö M, Clayton HM: Modelling rein tension during riding sessions using the generalised additive modelling technique. Comp Exerc Physiol 2018: 14(4): 209–221. DOI 10.3920/CEP180017.

10 Egenvall A, Eisersiö M, Roepstorff L: Pilot study of behavior responses in young riding horses using two methods of making transitions from trot to walk. J Vet Behav 2012: 7: 157–168. DOI 10.1016/j.jveb.2012.02.003.

11 Egenvall A, Roepstorff L, Rhodin M, Eisersiö M, Clayton HM: Maximum and minimum peaks in rein tension within canter strides. J Vet Behav 2016: 14: 94–99. DOI 10.1016/j.jveb.2016.03.007.

12 Egenvall, A. et al., 2019. Rein tension in transitions and halts during equestrian dressage training. Animals, 9(10), 712.

13 Eisersiö M, Rhodin M, Roepstorff L, Egenvall A: Rein tension in eight professional riders during regular training sessions. J Vet Behav 2015: 10(5): 419–426. DOI 10.1016/j.jveb.2015.05.004.

14 Eisersiö, M. et al., 2025. What is reinforced? The timing of the release of rein tension... Applied Animal Behaviour Science.

15 Farmer K, Krueger K, Byrne RW: Visual laterality in the domestic horse (Equus caballus) interacting with humans. Anim Cogn 2010: 13(2): 229–238. DOI 10.1007/s10071-009-0260-x.

16 Hartmann E, Rydberg A, Gunnarsson S, Jansson H: Associations between driving rein tensions and drivers' reports of the behaviour and driveability of Standardbred trotters. Appl Anim Behav Sci 2022: 250: 105726. DOI 10.1016/j.applanim.2022.105726.

17 Heleski CR, McGreevy PD, Kaiser LJ, Lavagnino M, Tans E, Bello N, Clayton HM: Effects on behaviour and rein tension on horses ridden with or without martingales and rein inserts. Vet J 2009; 181: 56–62. DOI 10.1016/j.tvjl.2008.01.01

18 Hoffmann K: An introduction to stress analysis and transducer design using strain gauges. HBM Test Meas 2012: 257.

19 Klapper R, Upham P: The impact of micro-firm everyday practices on sustainable development in local communities. In: Idowu SO, Capaldi N, Zu L, Gupta AD (eds), Encyclopedia of Corporate Social Responsibility. Springer, Berlin, 2015. DOI 10.4337/9781849808248.00021.

20 König von Borstel U, Glißman C: Alternatives to conventi-onal evaluation of rideability in horse performance tests: suitability of rein tension and behavioural parameters. PLoS ONE 2014: 9(1). DOI 10.1371/journal.pone.0087285.

21 Krueger K, Schwarz S, Marr I, Farmer K: Laterality in horse training: psychological and physical balance and coordination and strength rather than straightness. Animals 2022: 12(8): 1042. DOI 10.3390/ani12081042.

22 Kuhnke S, König von Borstel U: A comparison of different established and novel methods to determine horses' laterality and their relation to rein tension. Front Vet Sci 2022: 9: 789260. DOI 10.3389/fvets.2022.789260.

23 Kuznetsova A, Brockhoff PB, Christensen RHB: ImerTest – Tests in linear mixed effects models. R package version 3.1-3, 2017. Available: https://cran.r-project.org/package=ImerTest.

24 Münz A, Eckardt F, Witte K: Horse-rider interaction in dressage riding. Hum Mov Sci 2014: 33(1): 227–237. DOI 10.1016/j.humov.2013.09.003.

25 O'Neill M: The effect of rein type and bit type on rein tension in the ridden horse. ResM thesis, University of Plymouth, 2018.

26 OpenAI: ChatGPT. Version 4, San Francisco, California, USA, 2023. Available: www.chatgpt.com.

27 Piccolo L, Kienapfel K: Voluntary rein tension in horses when moving unridden in a dressage frame compared with ridden tests of the same horses – a pilot study. Animals 2019: 9(6). DOI 10.3390/ani9060321.

28 Posit Software PBC: RStudio – Integrated Development Environment for R. Version 2025.05.1, Boston, MA, USA, 2025. Available: https://posit.co.

29 Python Software Foundation: Python. Version 3.9, Beaverton, Oregon, USA, 2021. Available: www.python.org.

30 R Core Team: R – A language and environment for statistical computing. Version 4.5.1, Vienna, Austria: R Foundation for Statistical Computing, 2024. Available: https://www.R-project.org.

31 Schweizerischer Verband für Pferdesport: Ethik-Codex. Available: https://swiss-equestrian.ch/pferdewelt/ethik-codex.

32 SciPy Community: Signal processing (scipy.signal). Available: https://docs.scipy.org/doc/scipy/tutorial/signal.html.

33 Siemens AG: LMS Tecware. Leuven, Belgium, Version 3.13, 2022. Available: https://www.siemens.com/de/de.html.

[34] Toft K, et al.: Evaluation of dynamic structural disorders in the upper airways and applied rein tension in healthy dressage horses during riding in different gaits and head–neck positions. J Equine Vet Sci 2020: 87: 102934. DOI 10.1016/j.jevs.2020.102934.

[35] Uldahl M, Clayton HM: Lesions associated with the use of bits, nosebands, spurs and whips in Danish competition horses. Equine Vet J 2019: 51(2): 154–162. DOI 10.1111/evj.12827.

[36] Veen I, Killian D, Vlaminck L, Vernooij JCM, Back W: The use of a rein tension device to compare different training methods for neck flexion in base level trained Warmblood horses at the walk. Equine Vet J 2018: 50(6): 825–830. DOI 10.1111/evj.12831.

[37] Warren-Smith AK, Curtis RA, Greetham L, McGreevy PD: Rein contact between horse and handler during specific equitation movements. Appl Anim Behav Sci 2007: 108(1–2): 157–169. DOI 10.1016/j.applanim.2006.11.017.

[38] Warren-Smith AK, Curtis RA, McGreevy PD: A low cost device for measuring the tensions exerted on domestic horses by riders and handlers. Proc First Int Equit Sci Symp 2005: January: 44–55.

[39] Wolframm I: The Science of Equestrian Sports. Routledge, London and New York, 2014.

[40] Zwick Roell: Universal Testing Machine Z250. Ulm, Germany, 2022. Available: www.zwickroell.com.

[50] Average peak values of rein tension per gait for each team. (A) Average of peak values for all the teams, (B) values for teams 1 and 3, both teams with rider A (see details in Table 3), (C) average of peak values for teams 2 and 4, both teams with rider B (see details in Table 3).

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