

From Measurement to Meaning: Shifting Focus Toward Positive Welfare Indicators

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Over the past decade, equitation science has transitioned from a relatively fragmented, welfare-driven field into a methodologically sophisticated discipline spanning behavior, cognition, physiology, and technology. As societal expectations around animal use intensify, the field is moving beyond questions of how horses are trained or managed. Instead, the focus is shifting toward more fundamental questions of how horses experience their environment and how we, as their human caretakers, can both alleviate negative experiences and enhance well-being through positive interventions in their lives.

1. Technological Advances and the Measurement Revolution

The most visible advances in equitation science remain technological, marked by a decisive shift from controlled laboratory measurement toward field-deployable, continuous sensing systems. Inertial measurement units (IMUs) are now well validated for gait analysis and lameness detection, performing comparably to traditional laboratory methods while being deployable under real training conditions [1,2]. Networked sensor systems integrating GPS, heart rate monitoring, and movement data enable population-level welfare assessment, demonstrating measurable physiological responses to environmental stressors in situ [3]. Smart textiles further suggest that continuous, non-invasive monitoring of respiratory, cardiac, and locomotor parameters is becoming technically feasible [4]. Yet reviews in both the Equine Veterinary Journal and the Journal of Equine Veterinary Science converge on a more cautious conclusion: while technology is advancing rapidly, challenges remain in validation, durability, and the integration of physiological and psychological indicators [5,6]. The field has acquired the tools to measure, but is still refining how to interpret them. Future progress will depend not only on hardware refinement but also on developing robust interpretive frameworks that connect sensor outputs to meaningful welfare constructs.

2. Automated Welfare Assessment: Progress and Limitations

Parallel advances in automated welfare assessment are beginning to close the observation gap that has historically constrained behavioral research. Machine-learning approaches now allow high-accuracy classification of equine behavior from wearable sensors, while video- and accelerometry-based systems increasingly

detect pain-related behaviors, physiological stress responses, and changes associated with clinical conditions and sleep quality [7,8]. Despite this progress, most systems remain focused on detecting the absence of negative states rather than the presence of positive ones. This reflects a broader conceptual gap within equitation science, where research has historically prioritized negative welfare and affective states, partly because these are better studied and supported by more developed diagnostic tools.

Similar concerns within human psychology contributed to the emergence of "positive psychology" at the turn of the century [9], shifting attention beyond the treatment of pathology toward the conditions that enable a good life. While not all aspects of this framework translate directly to equitation science, the growing emphasis on positive welfare, agency, and behavioral flexibility suggests a comparable transition within the equine sector. The development of validated tools capable of identifying positive affective states will become increasingly important for a more comprehensive understanding of equine welfare.

3. The Critical Role of Horse–Human Interaction

The horse–human interaction literature highlights complementary concerns that extend beyond the animal itself. Horses are highly sensitive to human physiological and behavioral cues, responding to stress, posture, and emotional state in ways that directly affect interaction quality [10–12]. Experimental work demonstrates that human stress measurably alters horse behavior, reducing affiliative signals and increasing conflict-related responses [13]. Systematic reviews suggest that many ridden and handled contexts constrain horses to such an extent that genuine expressions of positive affect become difficult to detect [11], while in elite sport the horse–rider relationship is variably framed as central, secondary, or even conflicting with performance goals [14]. Industry expert perspectives often assume welfare is adequate where regulatory frameworks exist, focusing on veterinary or physical health aspects rather than the capacity to display natural behaviors, positive affective states, and species-typical interactions [15–17]. The critical influence of the human, shaping management, handling, and riding practices both implicitly and explicitly, remains systematically underplayed. Addressing this gap requires research designs that treat the horse–human relationship as a dynamic, bidirectional system rather than a unidirectional influence on an animal subject.

4. The Role of the Journal

Since its establishment, the **International Journal of Equine Science (IJES)** has emerged as an important platform for advancing interdisciplinary research across equine welfare, behavior, cognition, and the broader contexts in which horses are kept and used. Publication trends over recent years reflect the field's evolving priorities. Foundational work on welfare perceptions has highlighted how stakeholder assumptions surrounding equine welfare may overlook affective states, psychological health, and opportunities for species-typical behavior [18]. Research on training practices has identified inconsistencies in terminology and method reporting, reinforcing the need for greater standardization and clearer communication within the field [19]. The journal has also published work examining the psychological and occupational dimensions of equestrianism, including the relationship between technology, performance, and safety [20], injury experiences among racing staff [21], and workforce challenges affecting both human and equine welfare [22]. In parallel, research on coaching and education has explored how influential figures within equestrian communities perceive their role in shaping more sustainable futures for the sector [23], while studies on head–neck positions in ridden horses have contributed evidence relevant to welfare assessment and judging standards [24]. Collectively, these contributions illustrate the journal's capacity to connect empirical research with practical and regulatory concerns.

5. Conclusion

Equestrianism has been a late adopter of sports science integration and data-driven approaches compared to other sectors, likely due to deeply embedded traditional practices that do not align with modern shifts in societal attitudes toward animals in sport. This presents both a challenge and an opportunity: by embracing interdisciplinary research, open data, and transparent welfare frameworks, the equestrian sector can move from a posture of survival to one of thriving—demonstrating that horses can have a good life, not despite but because of their interaction with humans.

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Evaluating the Relationship Across Physical Activity Domains and Chronic Pain in Adult American Equestrians: A Secondary Analysis

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Abstract

Chronic pain (CP) in equestrians may disrupt rider–horse movement patterns, communication, and welfare. Physical activity (PA) is used to manage CP in other populations. Equestrians engage in high PA across equestrian (EqA), barn work (BW), and non-EqA domains, yet still report high CP rates. This study aims to explore risk and protective PA factors across domains associated with self-reported CP in American equestrians. Secondary analysis of a cross-sectional survey of adult American equestrians ($n = 1,612$). All variables were categorical (EqA, BW, and non-EqA volume; participation level; BW tasks). Chi-square tests informed forward binary logistic regression examining odds (ORs) of reporting CP across PA domains. The sample's participation level was 23.0% professionals, 44.5% amateurs, and 32.5% recreational equestrians, with 45% experiencing CP, most commonly in the back (27.8%). Recreational riders had lower odds of experiencing CP ($OR = 0.6$, $P < 0.001$), chronic lower-leg ($OR = 0.47$, $P = 0.004$), and neck ($OR = 0.57$, $P = 0.01$) pain than professionals. Regardless of participation level, equestrians engaging in categories ≤ 5 hours/week of EqA had lower odds ($OR = 0.46$ – 0.62 , $P = 0.001$ – 0.04) of reporting chronic back pain compared with those spending ≥ 15.5 hours/week. Regular running was protective against reporting CP, particularly in the back ($OR = 0.62$, $P = 0.007$) and pelvic ($OR = 0.50$, $P = 0.02$) regions. Participation level emerged as the primary risk factor for CP, followed by EqA volume for chronic back pain. Higher EqA workloads may exceed adaptive capacity regarding chronic back pain, underscoring the need for context-specific prevention strategies addressing workload management, such as physical training programs scaled to participation level and consideration of equipment fit (i.e., saddle).

Keywords

Horseback riding; risk factors; protective factors; pain prevalence; human–animal interactions

1. Introduction

Chronic pain (CP) is pain (of mild to severe intensity) that persists or recurs for longer than three months after the anticipated healing of the initial injury [1]. CP has been found to affect a wide range of equestrians (25–88%) depending on discipline and participation level [2–8]. It has been reported that 56.1% of American equestrians self-reported experiencing CP, with professionals at 1.5 times greater odds of reporting CP than amateur and recreational equestrians [9]. Management strategies for CP often target modifiable

risk factors related to the development and maintenance of CP, including sedentary lifestyle, poor or limited social interactions, and manual labor [10]. A common strategy to self-manage CP is engaging in physical activity (PA), which helps improve and maintain physical and mental functionality and reduce the severity of comorbidities (e.g., poor sleep, depression) [11,12].

Equestrian activities are a common form of PA and include mounted (i.e., riding or driving a carriage) and unmounted activities (i.e., caring for the horse and completing barn

work). According to the most recent American Horse Council report, although only 1.2% of households in the United States (U.S.) own horses, an additional 19.4% participate in equestrian activities, with nearly half (48%) of those participants reporting an annual household income of <\$75,000 [13].

Equestrian PA presents a complex bi-directional relationship with CP development and recurrence. While equestrian activities are a beneficial form of PA shown to improve balance, muscular strength, physical fitness, flexibility, and mental health, there is also a high risk for acute and overuse injuries [14–20]. Acute injuries frequently result from falls, kicks, and other mechanisms associated with working with a live animal and often progress into persistent pain and other health consequences [8,9,21–25]. One study reported that 62% of riders experienced CP and headaches after sustaining a significant equestrian-related injury [25]. Overuse injuries arise from the repetitive forces and demands of riding and caring for horses [2,26,27]. Chronic back pain rates are as high as 88% in elite dressage riders and are thought to reflect the repetitive, cumulative spinal loading that occurs during riding [2,3,6]. Research further documents frequent CP in the neck, pelvic, and lower extremities across disciplines [5–8,28].

Pain development is multifaceted. In riders, it can arise not only from injury but also from muscle weakness or tightness that produces asymmetrical movement patterns, which in turn can impair balance and coordination [29]. When pain and asymmetry persist, riders may place uneven forces on the saddle and the horse's back, potentially contributing to back discomfort or pain in the horse over time [29–31]. Rider asymmetry can also interfere with clear rider–horse communication and degrade riding performance, increasing opportunities for confusion, frustration, and errors between the duo [5,7,8,29,32]. In addition to these frustrations, CP may negatively impact the equestrian's concentration and confidence, which can lead to errors in practice or competition, causing injury to the horse and rider [33,34]. Therefore, for both human quality of life and horse welfare purposes, understanding areas that may exacerbate CP development and recurrence in equestrians is critical.

Key determinants of overuse injury and CP development align with PA load and task demands, including participation level (i.e., professional, amateur, or recreational), discipline (i.e., dressage), hours spent riding, and saddle type and fit [3–9,35–37]. Time spent engaging in any activity typically scales with participation level, with professionals engaging the most, followed by amateurs and then recreational participants, and this pattern is consistent in equestrians [16,38,39]. In addition to the high volume of engagement, professional equestrians often work with younger, less experienced (green) horses that may be more reactive and increase the chance of injury occurrence [40]. The pattern of PA load and participation level in equestrians increases exposure to cumulative musculoskeletal stress, thus heightening the likelihood of acute and overuse injuries. The high risk of acute injuries, coupled with overuse injuries from accumulated musculoskeletal strain, facilitates the progression to and maintenance of CP. These patterns reveal some of the plausible mechanisms underlying the high CP rates in professional and elite equestrians currently observed [3,9,41]. Despite PA often helping alleviate pain, there is a clear dose-dependent

connection between PA load and CP among equestrians that has only been superficially examined. As equestrian involvement requires significant physical demands, a deepening understanding of the complex, dose-dependent relationship between PA and CP is critically needed.

Equestrians engage in three primary PA domains: equestrian PA (i.e., riding horses or driving a carriage), barn work PA, and non-equestrian PA (i.e., running or lifting weights). Prior work quantifying equestrian PA load suggests that amateur and professional equestrians ride between 8–9 hours/week with large standard deviations (5–7 hours/week), while recreational equestrians spend 6.4 ± 4.5 hours/week riding [16,39]. Notably, the highest prevalence of chronic back pain was reported among equestrians riding 7–8 hours/day, ≥ 5 days/week [2]. Despite participation level, barn work PA typically requires a greater weekly time commitment than riding to maintain the horse's health and welfare, regardless of the horse's training schedule [4,9,38,42,43]. Common tasks (e.g., cleaning stalls, carrying water buckets, stacking hay) are repetitive and often asymmetric, resembling manual labor and imposing substantial physical strain [4,42,44]. British equestrians who completed >2 hours/day of barn work had 1.6 times greater odds of reporting pain compared with those performing <1 hour/day, and nearly 90% of participants reported experiencing pain during barn work activities [5,28]. Despite the clear physical demands of barn work, few studies have examined the relationship between barn work volume and CP, especially within American samples. Finally, non-equestrian PA engagement varies widely (25–91%) across other sporting activities and physical training programs [7,8,16,39,45–47]. Considering the range of PA loads across these domains, a deeper examination of how PA loads relate to CP in equestrians is warranted.

Based on the bi-directional relationship between PA and CP, it is important to examine how the volume and type of PA across different domains are associated with self-reported CP. These relationships are particularly relevant for American equestrians, who have similar CP rates as international equestrians, but for where research evaluating CP is sparse. Therefore, the purpose of this study is to explore the risk and protective factors for self-reporting CP among American equestrians in relation to PA volume across three domains: equestrian activity, barn work, and non-equestrian physical activity.

2. Methods

2.1. Study Design & Data Source

The current study is a secondary analysis of data collected from a cross-sectional, survey-based study conducted in 2020–2021 through REDCap [48,49]. The survey included questions regarding demographics, equestrian participation, PA across the three domains, acute injury, and CP. The original study aimed to (1) evaluate PA participation among American equestrians and perceptions of equestrian activity being a sport by participation level and (2) evaluate the relationship between acute injury and CP among American equestrians of all levels of participation, experience, and age ranges [9,38,50]. The current manuscript is a secondary analysis that investigates a novel aspect of the dataset not addressed in previous manuscripts and is guided by a new set of research aims, inclusion and exclusion criteria,

and analyses that differ from the original objectives of the cross-sectional survey. This data analysis was approved by the University of Kentucky's Institutional Review Board under protocol number 56488.

2.2. Dataset Inclusion and Validation

The original dataset included 2,539 responses. For the secondary analysis, inclusion criteria were (1) survey completion; (2) consistent participation on a weekly basis over the past six months (yes/no) at the time of the original study; (3) age ≥ 18 years; (4) definitive answers to questions regarding CP (e.g., "yes" or "no," not "prefer not to answer"); and (5) definitive answers to sex, age, height, and body mass demographic questions (e.g., not "prefer not to answer"). Participants who did not ride consistently were excluded from the sample, as the authors were interested in equestrians experiencing CP while continuing to participate in equestrian PA regularly. Data validation included analysis for duplicates and responses in which the reported age was less than the years of participation in equestrian activities. Data marked as a duplicate or where the individual's years of participation in equestrian activity were greater than their age were excluded from the subset.

2.3. Questionnaire Details

All questions were categorical (binary and ordinal) and included basic demographics, participation level (recreational, amateur, or professional), and years of participation in equestrian activities. Individuals who reported consistently engaging in equestrian activities over the past six months selected the number of days they rode per week (daily, 5–6 days, 3–4 days, or 1–2 days). To evaluate equestrian PA, participants reported the average number of hours they rode per two-week period over the past six months. There were 14 categorical options ranging from "<3 hours/2 weeks" to ">80 hours/2 weeks." The final equestrian domain question asked how many different horses a participant rode in an average two-week span over the past six months, with options of one, two, 3–4, 5–6, 7–9, or ≥ 10 horses.

For the barn work PA domain, the first question asked whether the participant helped with barn work or prepared their horse for riding (yes/no) over the past six months. Branching logic allowed individuals who answered "yes" to provide binary responses to types of barn work activities completed (i.e., cleaning stalls) and ordinal responses to barn work PA volume and specific tasks (i.e., how many stalls were cleaned consecutively). Barn work PA volume had nine categories, ranging from "1–4 hours/week" to ">40 hours/week."

For the non-equestrian PA domain, individuals selected the types of PA they engaged in regularly (at least once every two weeks over the past six months) from a list of 24 options. The last option was "other," which allowed participants to provide other types of non-equestrian PA they engaged in regularly. Branching logic allowed participants to report their average intensity level for each activity selected (low, low-moderate, moderate, moderate-vigorous, or vigorous) and the average hours per two-week period spent participating in the activity.

The final section allowed participants to report whether they were experiencing CP (referred to as "general CP") using a simple yes/no response. If the participant selected "yes," they could select which anatomical region(s) they were experiencing CP in, with the options: head/face, neck, chest, back, breasts, abdomen, arms, hands, pelvis, genitals, upper leg, lower leg, and foot. Participants were allowed to select more than one anatomical region to reflect if they were experiencing CP in multiple regions. Throughout this manuscript, "regional CP" refers to CP in any of these anatomical regions. **Supplementary Materials** contain the survey questions used for this secondary analysis.

2.4. Data Cleaning

A detailed breakdown of the inclusion criteria and number of participants excluded from the original dataset using the new inclusion criteria is shown in **Figure 1**. Data cleaning and analysis were completed in SAS 9.4.

To allow for easier comparisons across PA domains and other studies, hours spent riding were converted to hours/week. For example, responses of "<3 hours/2 weeks" became "<1.5 hours/week." To address sparse categories while preserving the ordinal structure, categories with fewer than 5% of the sample reporting that category were merged with adjacent categories. Minimal collapsing was implemented to satisfy standard assumptions for contingency analysis (e.g., Pearson χ^2 : $\geq 80\%$ of expected cell counts ≥ 5 and none < 1) and applied consistently across variables. **Table 1** demonstrates how the equestrian and barn PA domain variables were reorganized.

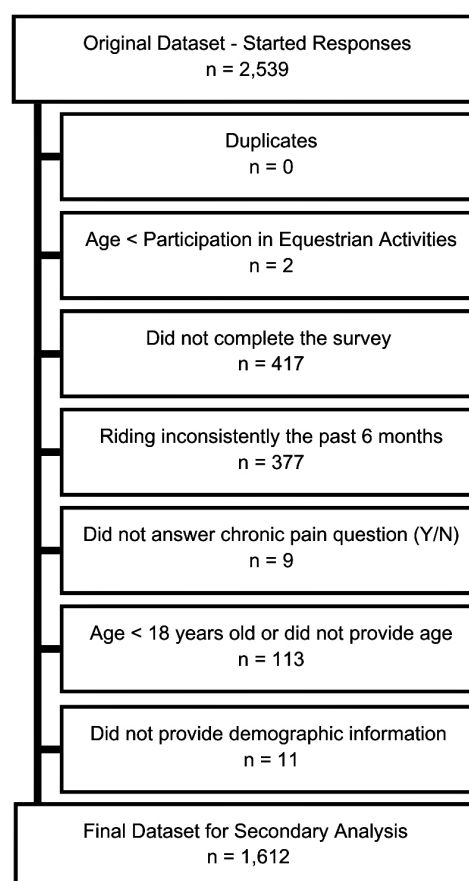


Figure 1: Flowchart of data included in the current study based on the inclusion criteria for the secondary analysis.

Table 1: Original categories and reorganized category frequencies to ensure sufficient sample size ($\geq 5\%$) for analysis.

Equestrian activity time					
Original categories			Reorganized categories		
Category	n	%	Category	n	%
<90 mins/week	88	5.5%	<90 mins/week	88	5.5%
1.5–3 hours/week	349	21.7%	1.5–3 hours/week	349	21.7%
3.5–5 hours/week	428	26.6%	3.5–5 hours/week	428	26.6%
5.5–7.5 hours/week	304	18.9%	5.5–7.5 hours/week	304	18.9%
8–10 hours/week	182	11.3%	8–10 hours/week	182	11.3%
10.5–12.5 hours/week ¹	74	4.6%	10.5–15 hours/week ¹	126	7.8%
13–15 hours/week ¹	52	3.2%	≥15.5 hours/week ²	135	8.4%
15.5–17.5 hours/week ²	18	1.1%			
18–20 hours/week ²	38	2.4%			
20.5–25 hours/week ²	21	1.3%			
25.2–30 hours/week ²	18	1.1%			
30.5–35 hours/week ²	15	0.9%			
35.5–40 hours/week ²	11	0.7%			
≥40 hours/week ²	14	0.9%			
Barn work time					
Original categories			Reorganized categories		
Category	n	%	Category	n	%
Barn work (no) [*]	106	6.6%	No barn work	106	6.6%
1–4 hours/week	439	27.4%	1–4 hours/week	439	27.4%
5–9 hours/week	392	24.5%	5–9 hours/week	392	24.5%
10–14 hours/week	271	16.9%	10–14 hours/week	271	16.9%
15–19 hours/week	114	7.1%	15–19 hours/week	114	7.1%
20–24 hours/week	98	6.1%	20–24 hours/week	98	6.1%
25–29 hours/week ¹	45	2.8%	25–34 hours/week ¹	84	5.2%
30–34 hours/week ¹	39	2.4%	≥35 hours/week ²	97	6.1%
35–39 hours/week ²	20	1.2%			
≥40 hours/week ²	77	4.8%			
11 missing			11 missing		
Number of horses ridden regularly in a two-week period over the last six months					
Original Categories			Reorganized Categories		
Category	n	%	Category	n	%
One horse	541	33.6%	One horse	541	33.6%
Two horses	500	31.1%	Two horses	500	31.1%
3–4 horses	331	20.6%	3–4 horses	331	20.6%
5–6 horses	121	7.5%	5–6 horses	121	7.5%
7–9 horses ¹	50	3.1%	≥7 horses ¹	115	7.2%

10+ horses ¹	65	4.0%			
	4 missing			4 missing	
Number of water buckets carried consecutively					
Original Categories			Reorganized categories		
Category	n	%	Category	n	%
Carry water buckets (No)*	727	48.6%	Does not carry water buckets	727	48.6%
1–2 buckets	371	24.8%	1–2 buckets	371	24.8%
3–4 buckets	146	9.8%	3–4 buckets	146	9.8%
5–6 buckets ¹	83	5.5%	5–10 buckets ¹	142	9.5%
7–10 buckets ¹	59	3.9%	>10 buckets	111	7.4%
>10 buckets	111	7.4%			
	115 missing			115 missing	
The maximum distance water buckets are carried					
Original categories			Reorganized categories		
Category	n	%	Category	n	%
Does not carry buckets	727	48.7	Does not carry water buckets	727	48.7
Up to 25 feet	316	21.1	Up to 25 feet	316	21.1
25–50 feet	261	17.5	25–50 feet	261	17.5
50–100 feet ¹	133	8.9	>50 feet ¹	190	12.7
>100 feet ¹	57	3.8			
	118 missing			115 missing	

^{1,2}Show which categories were combined to create the category with the coinciding number on the reorganized category side.

*Represents an original yes/no question about the task, which was used to create a "Does not complete" category for analysis purposes.

For hours per week of equestrian PA, the original 14 categories were collapsed into seven categories. The first five categories were retained, while the next two adjacent categories were combined to form "10.5–15 hours/week." The last seven categories all had low-frequency levels (0.68–2.4%) and were pooled into a "≥15.5 hours/week." For the number of horses ridden on a regular basis, the two highest categories were combined into ≥7 horses.

For barn work PA, the original nine options were collapsed into seven by keeping the first five categories unchanged, combining two adjacent categories into 25–34 hours/week, and pooling the two highest categories into ≥35 hours/week. Participants who answered "no" to completing barn work PA on a regular basis over the past six months were coded as 0 hours/week, yielding an eighth barn work category. The number of water buckets carried was reorganized so that two adjacent categories were merged to create a 5–10 bucket category. The maximum distance water buckets were carried was reorganized to create a >50 feet category.

For non-equestrian physical activities, low and low-moderate intensity responses, and moderate, moderate-vigorous, and vigorous responses were collapsed into "low intensity" and "moderate to vigorous intensity" for all activities. Similar to equestrian PA, non-equestrian PA domains were converted into hours/week. Hours spent participating in

each activity were then collapsed into ">2 hours/week" and "≥2 hours/week." A third category was created for participants who did not report participating in the activity.

2.5. Statistical Analysis

Statistical analysis was completed in SAS 9.4, with significance set at $P < 0.05$ for all tests. Frequencies and descriptive statistics were calculated for all independent (PA domain variables) and dependent variables (general and regional CP). Spearman correlation tests were used to examine relationships among ordinal independent variables, including equestrian PA, barn work PA, non-equestrian PA, number of horses ridden regularly, number of riding days per week, and participation level. To evaluate the relationships between general and regional CP for each independent variable, chi-square tests were used. Regional pain analyses were conducted when sufficient data were available, defined as expected cell counts ≥5 for at least 80% of cells. Based on expected cell counts, regional analyses were completed for the back, pelvis, lower leg, neck, and upper leg. Relationships that demonstrated significance ($P < 0.05$) with the chi-square tests were further analyzed using binary logistic regressions (1 independent variable) or forward-selection binary logistic regression (≥2 independent variables). If two ordinal variables had significant chi-square results and also demonstrated a moderate or stronger correlation ($|\rho| \geq 0.40$), they were both entered as predictors. If forward

selection retained both predictors of a correlated pair, multicollinearity was evaluated in the final model ($VIF > 5$ or condition index > 30). If multicollinearity was present, the variable with fewer missing responses was retained. When a response was missing for a predictor variable, that observation was not used in the analysis.

For binary logistic regressions, general CP or specific regional CP was always the dependent variable. The reference group for CP was consistently set to "yes." This directional choice enabled interpretation of all odds ratios (ORs) as increased or decreased likelihoods of reporting CP based on the predictor variables. All models were fitted using forward selection with an alpha level of 0.05. Results include ORs with 95% confidence intervals (95% CI) and *P*-values for all retained effects. The *c*-statistic summarizes model discrimination as the area under the curve. To evaluate overall model fit while penalizing model complexity, the Akaike Information Criterion (AIC) was reported, reflecting the trade-off between goodness of fit and the number of variables added to the model. AIC values indicate models that are better supported by the data, with no natural cutoff, and are only interpretable relative to other models within the same dataset. As a baseline of AIC without model comparison does not provide interpretable results, AIC reduction (AIC_R) was reported to provide a relative marker to determine which model represents the best fit for the dataset. AIC_R was defined as $AIC_R = AIC_{null} - AIC_{model}$. For AIC_R , larger positive values indicate greater improvement, 0 indicates no improvement, and negative values indicate worse fit than the null model.

Models were first fit separately for each of the three PA domains of interest: equestrian, barn work, and non-equestrian PA. Only significant variables identified by the chi-square tests for each model were included. Equestrian variables included participation level (reference: professional), equestrian PA (reference: ≥ 15.5 hours/week), and number of horses ridden regularly (reference: one horse). Barn work variables included completing barn work (reference: yes), barn work PA (reference: 1–4 hours/week), binary barn work activities (reference: yes), number of buckets carried (reference: 1–2 buckets), distance buckets were carried (reference: Up to 25 feet), and number of stalls cleaned (reference: > 10 stalls). For non-equestrian activities, only activities reported by $\geq 10\%$ of the sample were included to meet expected cell count for chi-square tests described above. The variables for models included binary physical activities (reference: yes, they participate in this activity) and the intensity time (low intensity and moderate-to-vigorous intensity) for each activity (reference: does not participate).

After individual domain models were fit, all predictors across domains with significant associations ($P < 0.05$) in the chi-square tests were entered into a multivariable model for general CP and each regional CP (when sample size allowed stable estimation). We report the final variables included in the final output for each model (individual domain and across domains). To evaluate different levels of

ORs, we also report ORs for significant models with varying reference groups, with reference groups provided in the Results section.

3. Results

3.1. Demographics

The final dataset included 1,612 responses, with the majority (96.0%) of the sample reporting that they were female. Participants' age was normally distributed across groups, with 14.9% aged 18–24, 22.6% aged 25–34, 19.1% aged 35–44, 13.2% aged 45–54, 17.7% aged 55–64, and 12.5% aged ≥ 65 years. A total of 45.2% reported experiencing general CP, with the most frequently reported region of CP being chronic back pain (27.8%). Other commonly reported sites of CP were the pelvis (10.4%), lower legs (9.1%), the neck (8.9%), and upper legs (7.1%). Less frequently reported regions for CP included the feet (5.0%), arms (4.4%), hands (4.0%), the face (1.7%), the abdomen (1.5%), the chest (1.2%), the breast (0.4%), and the genitals (0.2%). Of those reporting experiencing CP, 115 did not provide information regarding which region they were experiencing CP in. Of the 614 individuals who did report which region(s) they experienced CP in, 39.1% reported experiencing CP in only one region, 33.1% reported CP in two regions, 15.0% reported CP in three regions, 6.0% reported CP in four regions, and the remaining 6.8% reported CP in five or more regions.

Results of the Spearman correlation tests indicated only three pairs of variables with moderate or greater correlations. The number of horses ridden and participation level had a moderate positive correlation of $r^2 = 0.47$, $P < 0.001$. As the participation level increased from recreational to amateur to professional, the number of horses ridden regularly also increased. A similar relationship was found between equestrian PA time and the number of horses ridden, with a moderate positive correlation of $r^2 = 0.41$, $P < 0.001$. As the number of horses increased, so did the time spent engaging in equestrian PA. Finally, commitment per week and equestrian PA had a strong positive correlation of $r^2 = 0.61$, $P < 0.001$. As equestrian PA increased, so did the number of days per week the individual reported riding.

3.2. Equestrian Activity Domain

Table 2 presents the frequencies for the equestrian PA domain variables, as well as the *P*-values from the chi-square tests for those reporting CP general and those not reporting pain.

For general CP, participation level ($P = 0.007$) and the number of horses ridden ($P = 0.006$) had significant associations. The final model identified participation level as the only significant predictor for general CP ($P = 0.006$). The overall fit was acceptable (residual $\chi^2(4) = 6.25$, $P = 0.18$; $AIC_R = 6.21$; *c*-statistic = 0.54). Recreational (OR = 0.66, 95% CI: 0.51–0.87, $P < 0.01$) and amateurs (OR = 0.71, 95% CI: 0.55–0.91, $P < 0.01$) were less likely to report general CP than professionals. There were no significant differences between amateurs and recreational equestrians for reporting general CP (OR = 0.93, 95% CI: 0.74–1.17, $P = 0.55$).

Table 2: Summary of equestrian and barn work volume for the entire sample and stratified by those who reported experiencing chronic pain and those who reported no pain, with *P*-values from the chi-square test results.

	Entire sample		Chronic pain group		No pain group		
	n	%	n	%	n	%	P-value
Participation level							
Professional	371	23.0	194	26.6	177	20.1	0.007*
Amateur	718	44.5	314	43.1	404	45.7	
Recreational	523	32.5	221	30.3	302	34.2	
Equestrian physical activity (hours/week)							
<1.5	88	5.5	36	4.9	52	5.9	0.25
1.5–3.0	349	21.6	139	19.1	210	23.8	
3.5–5.0	428	26.6	194	26.6	234	26.5	
5.5–7.5	304	18.9	142	19.5	162	18.3	
8.0–10.0	182	11.3	90	12.3	92	10.4	
10.5–15.0	126	7.8	62	8.5	64	7.3	
≥15.5	135	8.4	66	9.1	69	7.8	
Days ridden per week							
Daily	116	7.3	59	7.0	66	7.6	0.47
5–6	425	26.7	197	27.4	228	26.1	
3–4	692	43.5	321	44.7	371	42.5	
1–2	359	22.5	150	20.9	209	23.9	
	20 missing		11 missing		9 missing		
Number of horses ridden on a regular basis							
One	541	33.6	216	29.8	325	36.8	0.006*
Two	500	31.1	222	30.6	278	31.5	
Three–Four	331	20.6	163	22.4	168	19.1	
Five–Six	121	7.5	62	8.5	59	6.7	
≥Seven	115	7.1	63	8.7	52	5.9	
	4 missing		3 missing		1 missing		

*Denotes significant *P*-values where $\alpha < 0.05$.

Percentages are calculated by column within each group for each variable; for example, adding the chronic pain percentages by participation level equals 100%.

For chronic back pain, participation level ($P = 0.01$) and equestrian PA ($P = 0.003$) were significant. The final model included only equestrian PA ($P = 0.002$). The overall fit was acceptable (residual $\chi^2(2) = 2.11$, $P = 0.34$; $AIC_R = 8.61$; c-statistic: 0.57). Riding <1.5 hours/week had lower odds of reporting chronic back pain than riding 8–10 hours/week (OR = 0.49, 95% CI: 0.27–0.91, $P = 0.02$) and ≥15.5 hours/week (OR = 0.42, 95% CI: 0.22–0.79, $P < 0.01$). Similarly, riding 1.5–3 hours/week was associated with lower odds of reporting chronic back pain compared with riding 5.5–7.5 hours/week (OR = 0.67, 95% CI: 0.47–0.95, $P = 0.03$).

8–10 hours/week (OR = 0.53, 95% CI: 0.36–0.80, $P < 0.01$), 10.5–15 hours/week (OR = 0.58, 95% CI: 0.37–0.91, $P = 0.02$),

and ≥15.5 hours/week (OR = 0.46, 95% CI: 0.3–0.7, $P < 0.001$). Finally, riding 3.5–5 hours/week was 39% less likely to report chronic back pain than those riding ≥15.5 hours/week (OR = 0.61, 95% CI: 0.41–0.92, $P = 0.02$).

Chi-square tests revealed no significant associations in the equestrian domain for chronic pelvic pain. For chronic lower leg pain, only the participation level had a significant association ($P = 0.0074$). A binary logistic model with no forward selection showed that with participation level, the model fit improved (Wald $\chi^2(2) = 9.55$, $P < 0.01$; $AIC_R = 6.46$). Recreational equestrians were less likely to report chronic lower leg pain than professionals (OR = 0.49, 95% CI: 0.30–0.80, $P < 0.01$) and amateurs (OR = 0.54, 95% CI: 0.34–0.87, $P < 0.01$). There

were no significant differences between amateurs and professionals (OR = 0.90, 95% CI: 0.60–1.34, $P = 0.61$).

Participation level ($P = 0.04$) and the number of horses ridden ($P = 0.04$) were both significantly associated with reporting chronic neck pain. The final model included only participation level ($P = 0.04$). Model fit improved modestly compared with not including participation level (residual $\chi^2(4) = 5.7$, $P = 0.22$; AIC_R = 2.37; c-statistic: 0.56). Recreational equestrians (OR = 0.57, 95% CI: 0.36–0.90, $P = 0.01$) were less likely to report chronic neck pain than professional equestrians. There was no difference between amateurs and recreational equestrians (OR = 1.20, 95% CI: 0.76–1.76, $P = 0.44$), or between amateurs and professional equestrians (OR = 0.65, 95% CI: 0.43–1.01, $P = 0.052$). There were no significant associations in the equestrian domain for upper leg CP, and all other regional CP did not have a large enough sample to run models.

3.3. Barn Work Activity Domain

Across the sample, 93.4% reported completing barn work, and 11 people did not answer the barn work questions and were excluded from the analysis. **Table 3** presents the frequencies for the entire sample and for general CP (no pain versus reports of experiencing CP) for barn work PA and individual barn work tasks. Grooming horses was the most common task reported, while dragging hoses was the least common task reported.

Barn work time ($P = 0.004$), feeding horses ($P < 0.001$), carrying water buckets ($P < 0.001$), number of buckets carried ($P = 0.007$), maximum distance of buckets carried ($P = 0.003$), number of stalls cleaned consecutively ($P = 0.02$), and stacking hay ($P = 0.001$) were all significantly associated with reporting general CP. The final model included carrying water buckets ($P = 0.03$), feeding horses ($P < 0.001$), and the number of stalls cleaned ($P = 0.02$). The overall fit was acceptable (residual $\chi^2(13) = 11.14$, $P = 0.60$; AIC_R = 20.57; c-statistic: 0.58). Not carrying water buckets decreased the likelihood of reporting general CP by 24% compared with carrying them (OR = 0.76, 95% CI: 0.57–0.98, $P = 0.03$). Not feeding horses decreased the likelihood of reporting general CP by 40% compared with feeding horses (OR = 0.60, 95% CI: 0.44–0.82, $P < 0.01$). Cleaning no stalls increased the odds of reporting general CP by 1.5 compared with cleaning 1–2 stalls (95% CI: 1.1–2.1, $P < 0.01$). Cleaning 7–10 stalls (OR = 1.6, 95% CI: 1.02–2.4, $P = 0.04$) and >10 stalls (OR = 1.7, 95% CI: 1.1–2.7, $P = 0.02$) increased the odds of reporting general CP compared with cleaning only 1–2 stalls.

Barn work time ($P = 0.004$), feeding horses ($P = 0.005$), dragging hoses ($P = 0.04$), stacking hay ($P = 0.01$), and the number of stalls cleaned consecutively ($P = 0.02$) all had significant associations with reporting chronic back pain. The final model identified feeding ($P < 0.001$) and the number of stalls cleaned ($P = 0.02$) as significant predictors. Model fit

was acceptable (residual $\chi^2(8) = 10.69$, $P = 0.22$; AIC_R = 15.37; c-statistic: 0.58). Not feeding horses was associated with a 48% decrease in the odds of reporting chronic back pain (OR = 0.52, 95% CI: 0.37–0.74, $P < 0.001$) compared with feeding horses. Compared with cleaning 1–2 stalls, not cleaning stalls increased the odds of reporting chronic back pain by 1.4 (95% CI: 1.02–2.0, $P = 0.04$). Cleaning 7–10 stalls (OR = 1.6, 95% CI: 1.02–2.5, $P = 0.04$) and >10 stalls (OR = 1.9, 95% CI: 1.2–3.1, $P < 0.01$) were associated with greater odds of reporting chronic back pain than cleaning 1–2 stalls. Cleaning 3–4 stalls (OR = 0.52, 95% CI: 0.32–0.86, $P = 0.01$) and cleaning 5–6 stalls (OR = 0.56, 95% CI: 0.32–0.98, $P = 0.04$) decreased the odds of reporting chronic back pain compared with those who reported cleaning >10 stalls.

For chronic pelvic pain, the only variable in the barn work domain with a significant association was the number of stalls cleaned consecutively ($P = 0.01$). A binary logistic model with no forward selection showed that the number of stalls cleaned improved the model fit modestly (Wald $\chi^2(5) = 14.05$, $P = 0.02$; AIC_R = 3.80). Relative to cleaning 1–2 stalls, not cleaning stalls increased the odds of reporting pelvic pain (OR = 1.6, 95% CI: 1.02–2.6, $P = 0.04$), as did cleaning >10 stalls (OR = 3.1, 95% CI: 1.6–5.9, $P < 0.01$).

For chronic lower leg pain, only the number of water buckets carried showed a significant association ($P = 0.02$). The final model fit improved modestly with the addition of the number of water buckets carried (Wald $\chi^2(4) = 11.11$, $P = 0.02$; AIC_R = 2.86). Carrying 5–10 water buckets increased the odds of reporting chronic lower leg pain by 2.1 (95% CI: 1.2–3.6, $P < 0.01$) compared with those who did not carry water buckets. Carrying >10 buckets increased the odds of reporting chronic lower leg pain by 2.5 compared with carrying 3–4 buckets (95% CI: 1.01–6.2, $P = 0.04$). Moreover, carrying no buckets (OR = 0.48, 95% CI: 0.28–0.82, $P < 0.01$) and carrying 3–4 buckets (OR = 0.33, 95% CI: 0.14–0.78, $P = 0.01$), compared with 5–10 buckets, decreased the likelihood of reporting chronic lower leg pain. There were no significant associations between any barn work domain predictors and any other regional CP.

3.4. Non-Equestrian Physical Activity Domain

The most common (65.0%) non-equestrian PA was walking. The non-equestrian activities with sufficient counts for analyses, aside from walking, included stretching (28.3%), hiking (28.0%), resistance training (25.9%), yoga (22.0%), running (15.9%), aerobics (12.5%), and cycling (10.9%). Other forms of non-equestrian PA were less common and were not evaluated in depth: general play (9.4%), Pilates (7.4%), interval training (6.9%), swimming (6.5%), elliptical (training) (6.1%), kayaking/canoeing/paddle boarding (5.7%), circuit training (4.7%), endurance training (3.5%), exercise ball/fit-ball (3.0%), dancing (2.9%), barre (2.8%), group sports (1.9%), boxing/kickboxing (1.7%), water aerobics/calisthenics (1.2%), and martial arts (0.6%).

Table 3: Barn work domain variables, including physical activity per week, individual binary barn tasks, and ordinal detailed barn task information.

	Entire sample		Chronic pain group		No pain group		
	n	%	n	%	n	%	P-value
Barn work physical activity (hours/week)							
No barn work	106	6.6	51	7.1	55	6.3	0.004*
1–4	439	27.4	164	22.7	275	31.3	
5–9	392	24.5	186	25.7	206	23.5	
10–14	271	16.9	126	17.4	145	16.5	
15–19	114	7.1	49	6.8	65	7.4	
20–24	98	6.1	46	6.4	52	5.9	
25–34	84	5.3	45	6.2	39	4.4	
≥35	97	6.1	56	7.7	41	4.7	
	11 missing		6 missing		5 missing		
Feeding							
No	483	30.0	187	25.7	296	33.5	<0.001*
Yes	119	70.0	542	74.3	587	66.5	
Carry water buckets							
No	840	52.1	346	47.5	494	56.0	<0.001*
Yes	772	47.9	383	52.5	389	44.0	
Number of water buckets carried							
None	727	48.6	292	43.4	435	52.8	0.007*
1–2 buckets	371	24.8	178	26.5	193	23.4	
3–4 buckets	146	9.8	72	10.7	74	9.0	
5–10 buckets	142	9.5	73	10.8	69	8.4	
≥11 buckets	111	7.4	58	8.6	53	6.4	
	115 missing		56 missing		59 missing		
Maximum distance water buckets are carried							
Does not carry	727	48.7	292	43.4	435	53.0	0.003*
Up to 25 feet	316	21.2	158	23.5	158	19.2	
25–50 feet	261	17.5	125	18.6	136	16.6	
>50 feet	190	12.7	98	14.6	92	11.2	
	118 missing		56 missing		62 missing		
Dragging hoses							
No	907	56.3	378	51.8	529	59.9	0.001*
Yes	705	43.7	351	48.2	354	40.1	
Cleaning stalls							
No	620	38.5	273	37.5	347	39.3	0.45
Yes	992	61.5	456	62.5	536	60.7	

Number of stalls cleaned consecutively							
No stalls cleaned	507	34.0	219	32.6	288	35.1	0.02*
1–2 Stalls	399	26.7	165	24.6	234	28.5	
3–4 Stalls	248	16.6	113	16.8	135	16.4	
5–6 Stalls	134	9.0	59	8.8	75	9.1	
7–10 Stalls	109	7.3	60	8.9	49	6.0	
>10 Stalls	95	6.4	55	8.2	40	4.9	
	120 missing		58 missing		62 missing		
Equipment used to help clean stalls							
Wheelbarrow/handcart	728	73.6	330	72.5	398	74.5	0.49
Trailer on ATV/tractor	116	11.7	50	11.0	66	12.4	
Tractor buckets	79	9.0	41	9.0	38	7.1	
Other	66	6.7	34	7.5	32	6.0	
	623 missing		274 missing		349 missing		
Clean aisles							
No	756	46.9	325	44.6	431	48.8	0.09
Yes	856	53.1	404	55.4	452	51.2	
Stacking hay							
No	820	50.9	339	46.5	481	54.5	0.001*
Yes	792	49.1	390	53.5	402	45.5	
Grooming horse(s)							
No	266	16.5	124	17.0	142	16.1	0.62
Yes	1,346	83.5	605	83.0	741	83.9	
Tacking up/putting tack on the horse(s)							
No	359	22.3	161	22.1	198	22.4	0.87
Yes	1,253	77.7	568	77.9	684	77.6	
Cleaning tack							
No	577	35.8	255	35.0	322	36.5	0.53
Yes	1,035	64.2	474	65.0	561	63.5	
Leading horses							
No	563	34.9	237	32.5	326	36.9	0.06
Yes	1,049	65.1	492	67.5	557	63.1	

*Denotes significant chi-square results between pain and no pain group with α set to 0.05.

Percentages are calculated by column within each group for each variable, for example, adding the chronic pain group percentages by barn work physical activity equals 100%.

For reporting general CP, running ($P < 0.001$) and resistance training ($P = 0.003$) had significant associations. Moderate-to-vigorous intensity for both non-equestrian physical activities also had significant associations with reporting general CP ($P < 0.01$). The forward-selection binary logistic regression model identified lifting ($P = 0.046$) and moderate-to-vigorous running intensity ($P < 0.001$) as significant

predictors in the final model. Model fit was appropriate (residual $\chi^2(3) = 0.14$, $P = 0.99$; $AIC_R = 19.11$; c-statistic: 0.55).

Engaging in resistance training decreased the odds of reporting general CP compared with those who did not engage in resistance training (OR = 0.79, 95% CI: 0.62–0.99, $P = 0.04$). Running for < 2 hours/week (OR = 0.59, 95% CI: 0.41–0.83, P

< 0.01) and running for ≥ 2 hours/week (OR = 0.39, 95% CI: 0.19–0.78, $P < 0.01$) decreased the odds of reporting general CP compared with those not running. There was no difference between those running <2 hours/week and those running ≥ 2 hours/week (OR = 1.51, 95% CI: 0.71–3.22, $P = 0.28$).

Similar to general CP, chronic back pain showed significant associations with running ($P = 0.003$) and resistance training ($P = 0.03$), as well as with moderate-to-vigorous intensity for both activities ($P < 0.05$). For the forward selection binary logistic regression model, only running ($P = 0.003$) was retained as a predictor in the final model. Model fit improved with the addition of running (residual $\chi^2(5) = 7.16$, $P = 0.21$; $AIC_R = 7.18$; c-statistic: 0.53). Running decreased the odds of reporting chronic back pain by 38% compared with not running (OR = 0.62, 95% CI: 0.44–0.85, $P < 0.01$).

Running was the only significant association with reporting chronic pelvic pain ($P = 0.01$). The binary logistic regression model fit improved modestly with the addition of running to the model (Wald $\chi^2(1) = 5.46$, $P = 0.02$; $AIC_R = 4.31$). Running decreased the odds of reporting chronic pelvic pain by 47% (OR = 0.53, 95% CI: 0.31–0.90, $P = 0.02$) compared with not running. No other regional CP showed significant associations with non-equestrian PA.

3.5. Across Physical Activity Domains

The final predictors included in the across-domain models for general and regional CP are presented in **Table 4**. The final binary logistic regression model for predicting general CP retained participation level ($P = 0.003$), moderate-vigorous running time ($P < 0.001$), and feeding horses ($P = 0.001$). The addition of these three predictors substantially improved model fit (residual $\chi^2(33) = 34.76$, $P = 0.38$; $AIC_R =$

35.51), and model discrimination was modest (c-statistic: 0.59). The final forward-selection binary logistic model for chronic back pain retained equestrian PA time ($P = 0.006$), running ($P < 0.001$), feeding horses ($P < 0.001$), and number of stalls cleaned ($P = 0.04$). Model fit improved with the inclusion of these predictors, and there was no evidence of lack of fit (residual $\chi^2(15) = 14.80$, $P = 0.47$; $AIC_R = 25.50$; c-statistic: 0.62). For chronic pelvic pain, only running and the number of stalls cleaned had significant associations. Model fit was acceptable (residual $\chi^2(2) = 4.40$, $P = 0.22$; $AIC_R = 8.35$; c-statistic: 0.57). For chronic lower leg pain, participation level and number of water buckets carried were entered into the model, and only participation level was retained ($P < 0.01$). Model fit improved with the addition of participation level (residual $\chi^2(4) = 8.78$, $P = 0.07$; $AIC_R = 6.57$; c-statistic: 0.57). Chronic neck pain had only one significant variable (participation level) across domains; model fit is reported above in the equestrian domain.

4. Discussion

This study explores the relationship between PA volume across three domains and its association with self-reported CP in American equestrians. This secondary analysis successfully evaluated the likelihood of reporting general and regional CP in relation to volume and engagement in activities across three domains: equestrian, barn work, and non-equestrian PA. Our findings reinforce a growing body of evidence that CP in equestrians is shaped by participation level and demonstrate a dose-dependent relationship across aspects of all three domains. The final models evaluating the likelihood of reporting general and regional CP across all three domains are the focus of the discussion.

Table 4: Final predictors for reporting general and regional CP across physical activity domains, with odds ratios. All reference variables are indicated in parentheses. For example, the first odds ratio below should be interpreted as: "Recreational equestrians are 40% less likely (1.00–0.60 = 0.4) to report general chronic pain compared with professionals."

Outcome	Predictor (reference)	Adjusted OR (95% CI)	P-value
General chronic pain	Participation level		
	Recreational (Professional)	0.60 (0.45–0.80)	<0.001*
	Amateur (Professional)	0.74 (0.57–0.97)	0.03*
	Recreational (Amateur)	0.81 (0.64–1.04)	0.09
	Feeding horses		
	No (Yes)	0.65 (0.50–0.83)	<0.001*
	Moderate-vigorous running		
	<2 hours/week (0 hours/week)	0.54 (0.38–0.77)	<0.001*
	≥ 2 hours/week (0 hours/week)	0.40 (0.20–0.81)	0.01*
Chronic back pain	<2 hours/week (≥ 2 hours/week)	0.75 (0.35–1.61)	0.46
	Equestrian physical activity		
	<1.5 hours/week (≥ 15.5 hours/week)	0.46 (0.23–0.91)	0.02*
	1.5–3 hours/week (≥ 15.5 hours/week)	0.47 (0.30–0.74)	0.001*
	3.5–5 hours/week (≥ 15.5 hours/week)	0.62 (0.40–0.96)	0.03*
	5.5–7.5 hours/week (≥ 15.5 hours/week)	0.72 (0.46–1.14)	0.16

	8–10 hours/week (≥ 15.5 hours/week)	0.90 (0.55–1.47)	0.66
	10.5–15 hours/week (≥ 15.5 hours/week)	0.74 (0.43–1.27)	0.28
	<1.5 hours/week (8–10 hours/week)	0.53 (0.34–0.81)	0.04*
	1.5–3 hours/week (8–10 hours/week)	0.51 (0.26–0.99)	0.003*
	Feeding horses		
	No (Yes)	0.54 (0.39–0.77)	0.007*
	Stalls cleaned consecutively		
	None (>10)	0.77 (0.47–1.28)	0.31
	1–2 (>10)	0.57 (0.35–0.93)	0.02*
	3–4 (>10)	0.53 (0.32–0.89)	0.01*
	5–6 (>10)	0.55 (0.31–0.97)	0.04*
	7–10 (>10)	0.83 (0.47–1.48)	0.53
	Running		
	Yes (No)	0.62 (0.44–0.88)	0.007*
Chronic pelvis pain	Stalls cleaned consecutively		
	None (>10)	0.48 (0.27–0.87)	0.01*
	1–2 (>10)	0.30 (0.16–0.57)	<0.001*
	3–4 (>10)	0.48 (0.25–0.92)	0.03*
	5–6 (>10)	0.50 (0.24–1.05)	0.07
	7–10 (>10)	0.27 (0.11–0.69)	0.006*
	Running		
	Yes (No)	0.50 (0.28–0.89)	0.02*
Chronic lower leg pain	Participation level		
	Recreational (Professional)	0.47 (0.28–0.79)	0.004*
	Amateur (Professional)	0.89 (0.59–1.35)	0.59
	Recreational (Amateur)	0.53 (0.33–0.84)	0.007*
Chronic neck pain	Participation Level		
	Recreational (Professional)	0.57 (0.36–0.89)	0.01*
	Amateur (Professional)	0.55 (0.43–1.01)	0.05
	Recreational (Amateur)	0.85 (0.56–1.30)	0.44

*Denotes significant odds ratio with significance set at $P < 0.05$.

Equestrian activities, specifically riding, are biomechanically complex and involve high-impact, repetitive movements transferred from the horse to the rider [2,6]. When evaluating the models including variables across all domains, two significant predictors from the equestrian activity domain emerged for reporting general and regional CP: participation level and weekly time spent engaging in equestrian activities.

Participation level emerged as the primary predictor of CP for general CP, chronic lower leg pain, and chronic neck pain. Participation level functions as a higher-order variable within the equestrian domain, as it typically drives equestrian PA volume and the number of horses ridden regularly.

Previous sport-specific research has identified that professionals have a higher rate of CP and acute injury compared with recreational and amateur athletes [51]. Consistent with that pattern, a larger subset of the present dataset reported that professional equestrians engaged in more riding and barn work than amateur and recreational riders [38] and were more likely to report acute injuries across most anatomical regions [9]. This load-dependent interpretation is further supported by work in equestrian populations showing that riders whose main occupation is riding have 1.76 times greater odds of reporting dysfunctional Roland–Morris Disability scores (≥ 4) than hobbyist riders and that professionals reported back pain in the previous month more frequently (56%) than amateurs (13%) [37,52].

Considering the past literature, the current findings point to a consistent, exposure-related pattern in which participation level is repeatedly associated with greater odds of reporting acute and CP across equestrian populations.

The final fitted model shows that recreational and amateur riders are less likely to report general CP than professionals. In this study, general CP refers to chronic pain in at least one body region. Participation level is moderately correlated with the number of horses ridden, suggesting that professional riders take on more mounts and therefore more varied movement patterns. For professional equestrians, their income and livelihood depend on their ability to ride and train horses, manage facilities, and provide lessons or clinics. Training horses requires conditioning, creating exercise tolerance specific to the riding discipline, and developing coordinated and balanced strength bilaterally [53,54]. Similar to humans, horses display natural movement asymmetries, which require creating balance through muscle strength and practice in a specific training program to decrease the likelihood of injury [53–55]. Prior work reports that riders working multiple horses per day are more likely to report back pain than those riding only one horse, which is a pattern consistent with pain linked to rider asymmetries and the repetitive high load of equestrian PA [9,26,27,30]. Riding several horses in a day increases movement variability and demands repeated postural adjustments, which may lead to increased musculoskeletal strain [25]. This relationship is likely bi-directional, as rider asymmetries can also influence the horse's movement, as pain itself can compromise posture and function. Eighty-five percent of riders reported that their pain negatively affected their riding performance by altering their position and range of motion, decreasing their concentration, and increasing fatigue [6]. The loop between pain and posture underscores the complexity of equestrian and equine biomechanics and highlights the need for future research to evaluate the bi-directional relationship between horse and rider asymmetries on each other.

Saddle fit likely contributes to the relationship between participation level and CP, particularly among riders who ride multiple horses. Although saddle type and fit were not assessed in this study, it is reasonable to infer that riders working with several horses use multiple saddles with variable fit. While saddle fit is often evaluated primarily for equine welfare, it also plays a critical role in rider posture and movement patterns [2,5,6]. Poor saddle fit has been associated with rider crookedness and equine thoracolumbar asymmetries, creating a feedback loop of uneven pressure, altered alignment, and asymmetric muscle strain in both horse and rider [30]. Riders using poorly fitted saddles are more likely to report worsening back pain [25]. More than 60% of dressage riders attributed their pain to saddle fit, with 59% reporting that their pain negatively impacted their performance [5]. Common issues identified by coaches, therapists, and saddle fitters include saddles that are too small, that slip to one side, or that shift the rider's weight forward, all of which can disrupt spinal alignment and increase strain on the neck and back [9,28,56]. While the current study lacks the information to evaluate the association between saddle fit and reports of CP, previous findings highlight the need to examine saddle fit in relation to equestrian CP in greater depth.

This evidence aligns with the current study's finding that professionals are at greater risk of chronic neck pain than recreational riders. Biomechanical analyses show that when vertical acceleration is transmitted from the sacrum to the cervical spine (C7) and head, peak acceleration decreases during the rising phase of the posting trot but does not decrease consistently during sitting trot, suggesting that the neck experiences greater forces during sitting phases [56]. Sitting trot requires riders to absorb forces with every step, whereas posting trot allows them to attenuate forces differently during the sitting and posting phases. It can be inferred that spending more time on horses increases the time spent in sitting trot, which would therefore result in greater amount of cervical loading in professional equestrians than in those who engage in lower levels of participation. High rates of chronic neck pain could be detrimental, as correct alignment and coordinated movement of the neck, trunk, and pelvis are essential for maintaining rider balance and control [57–59]. In riders with neck pain (acute or chronic), the ability of cervical muscles to absorb forces and stabilize the head is likely compromised, which can impair rider balance and coordination and increase physical demands on the horse. Considering that participation level is a key factor in this study, future research should examine saddle fit as a modifiable contributor to musculoskeletal strain and pain in equestrians, particularly among professionals who experience higher exposure and biomechanical load. Future studies should also evaluate the specific load and weekly volume riders spend in different gaits by participation level, and how this exposure pattern relates to both acute and chronic pain.

In the chronic back pain model, weekly equestrian PA volume is the primary predictor within the equestrian domain, with riders engaging in more equestrian PA having greater odds of reporting chronic back pain. Mechanical loads generated during riding are transmitted and attenuated through the spine [56]. When sustained over long durations, these forces create lumbar and thoracic loading comparable to occupational manual labor [26,27]. This pattern aligns with [2], which reports the highest prevalence of chronic low back pain among riders training ≥ 5 days per week for 7–8 hours per day. Rider-specific factors, such as reduced hip abductor flexibility and limited pelvic mobility, are also associated with greater odds of chronic back pain and promote asymmetrical movement patterns [29]. When these asymmetries occur in conjunction with prolonged saddle contact, they can amplify uneven loading for both horse and rider and may be further influenced by saddle fit and positioning. Considering these findings in conjunction with the preceding discussion on saddle-related factors, greater time spent in the saddle is consistently associated with higher spinal load, asymmetrical strain, and an increased likelihood of chronic back pain, regardless of participation level. Future research should compare rider biomechanics between riders with and without chronic back pain to clarify these mechanisms. Additionally, longitudinal studies are needed to evaluate pain avoidance across different PA domains, as the current study's cross-sectional design does not enable assessment of these relationships.

In addition to equestrian activity, the volume of barn work and related tasks represents a critical yet underrecognized

source of PA and mechanical loading among equestrians. It has been reported that 35% of professional international event riders feel that barn work contributes to their pain [6]. Another study found that 89.1% of amateur and recreational riders experience pain while performing stable duties, with 53.4% reporting CP [28]. Although the present study does not assess perceived pain sources, the consistency between these findings, despite potential cultural and geographic differences, suggests that barn work PA contributes meaningfully to musculoskeletal strain in equestrians.

In the current study, two barn work predictors (feeding and number of stalls cleaned consecutively) are associated with greater odds of reporting general and regional CP. Feeding tasks, while often routine, encompass numerous physically demanding motions such as lifting hay bales, filling and carrying hay nets, and moving feed bags that were not detailed in the current study's survey. These activities involve repetitive bending, carrying, and twisting motions. Equestrians who assist with feeding experience pain at higher odds align with the results of [28] which reported that approximately 40% of equestrians experience discomfort and 32.6% report severe to excruciating pain during barn work activities involving carrying [28]. While these prior findings [28] and the current study address distinctly different research questions, the findings collectively support the need for further research to evaluate which barn work tasks and sub-domains (i.e., carrying versus lifting) may serve as the most significant contributors to the onset of acute and chronic pain among equestrians. A deeper understanding of these mechanisms will inform the development of future targeted interventions that may include strength and ergonomic training, as well as improvements in equipment and facility design. These findings align with other studies identifying that prolonged, repetitive manual labor is a risk factor for developing musculoskeletal injuries and pain [28,60].

Analyses of the current dataset further indicate significantly greater odds of chronic pelvic and back pain among riders who clean more than ten stalls per week. This finding aligns with previous work, which reports that stall cleaning aggravates low back pain in over half of equestrians [52]. This relationship persists across various cleaning volumes and is not influenced by the method of waste removal, suggesting that cumulative workload, rather than equipment type, is a primary predictor of low back pain. This cumulative workload includes removing manure and urine-soaked bedding, which can weigh approximately 22.8 kg per horse per day [61]. Cleaning stalls is not a barn task that can be ignored, as it is a crucial component of maintaining facility cleanliness and horse welfare. The impact of these findings reveals the need to explore the musculoskeletal strain accumulated from barn work and to identify potential approaches to mitigate the risk of developing CP, such as modifying body mechanics and adjusting equipment used for barn work tasks. Moreover, these findings underscore the importance of evaluating the entire system (equine, equestrian, and environment/equipment) to comprehensively understand and address CP factors within the equestrian population [43].

Engaging in regular PA is well-documented as a method to improve numerous health outcomes, including CP [62–64].

Clinicians often recommend PA as a strategy to self-manage CP symptoms and maintain physical function [63,64]. The current study identifies that running is associated with a lower likelihood of reporting general CP, chronic back pain, and chronic pelvic pain. Specifically, aerobic PA is found to be an effective nonpharmacological and noninvasive therapeutic option for individuals with CP, as participating in aerobic PA can decrease pain sensitization [65,66]. In addition to reducing pain intensity, aerobic PA facilitates significant improvements in aerobic capacity, mental and physical components of quality of life, overall well-being, and depression-related symptoms for individuals with CP [66]. These effects are particularly prominent in individuals with chronic low back pain [66]. Therefore, equestrians who engage in running may be more likely to sustain higher levels of participation in other PA domains, such as equestrian and barn work PA. It is possible that this relationship is present due to selection bias and equestrians experiencing pain are avoiding engagement in other activities. Therefore, additional research is warranted to elucidate the direction of the relationship and potential mechanisms related to running and CP, as it is possible that the relationship exists as a result of equestrians self-selecting not to participate in specific activities due to the pain they are experiencing.

4.1. Limitations

These findings should be interpreted with caution, as the results may not be generalizable to all equestrian populations. The most prominent limitation of this study is the lack of a standardized definition of CP, with participants self-identifying as experiencing CP without requiring a formal diagnosis from a healthcare provider. Therefore, some participants may meet the diagnostic criteria for CP but did not self-report, and conversely, some participants may have self-reported CP inaccurately. As the focus of this study was to examine the relationship between domains of PA and CP, participants who were not consistently engaging in equestrian PA due to an acute injury or CP were excluded. Consequently, we are currently unable to identify the risk and protective factors associated with injuries or pain that may lead to temporary or permanent discontinuation of participation in equestrian PA. Information regarding pain characteristics (i.e., frequency, duration, and interference) was not collected. Thus, the findings cannot provide insight into a typical pain profile for this community. Due to the cross-sectional design of this study, the findings are inherently non-directional; however, they highlight meaningful associations that warrant further investigation.

Another limitation of this study is due to its survey-based design. Since the data was collected through an online survey across the U.S., it is possible that participants misinterpreted questions, resulting in inaccurate responses. We also acknowledge the potential selection bias of online surveys, and that individuals with pre-existing pain may limit their participation in any of these PA domains, as well as not participate in specific barn work tasks. This possibility underscores the need for longitudinal study designs to better disentangle and explore pain-driven behavioral modification. Despite these limitations, the findings provide valuable insights into patterns observed within the equestrian population.

4.2. Future Research

Future research should further investigate both risk and protective factors contributing to CP in equestrian populations, including a more detailed analysis of riding volume (i.e., walking, trotting, sitting trot, etc.) and saddle fit. Identifying how these variables interact with biomechanical strain, horse and rider asymmetries, muscle soreness, and CP may inform targeted, non-pharmacological interventions aimed at preventing the development of CP. Protective factors, such as engaging in moderate barn work volume and aerobic-based activity, should also be explored for their potential to enhance musculoskeletal resilience. Additionally, equestrians often report mental and emotional benefits from horse interaction; examining these psychosocial factors may offer insight into holistic strategies for CP management. Understanding why equestrians with CP maintain high physical activity levels, unlike other populations with CP, could help identify effective coping mechanisms that may be applied to other individuals affected by CP.

5. Conclusion

The current study contributes to a growing body of evidence demonstrating a strong relationship between CP in equestrians and their participation level. Regular engagement in running appears protective, while the findings support a dose-dependent relationship between equestrian PA load and chronic back pain, and between the number of stalls cleaned and chronic back and pelvic pain. Future research should evaluate changes in PA engagement across domains with consideration of acute pain, development of CP, and pain-avoidant behaviors longitudinally. Given that participation level is a significant predictor in models across PA domains, interventions should explore strategies to support professional equestrians by moderating daily riding volume and the number of stalls cleaned consecutively. Importantly, equestrians often experience CP yet continue to engage in PA, presenting a valuable opportunity to study CP in an active population. Ultimately, prevention strategies aimed at supporting long-term musculoskeletal health will be most effective when they are context-specific and account for the interaction among the rider, the horse, equipment/saddle factors, and the working environment.

Supplementary Materials

The **Supplementary Materials** include the questions from the original survey that were used for this secondary analysis.

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Authors' Contributions

E.A.O.: Conceptualization, Methodology, Formal analysis, Writing – original draft, Writing – review & editing, Project administration. K.I.T.: Conceptualization, Data curation, Writing – review & editing. M.M.K.: Conceptualization, Methodology, Formal analysis, Writing – original draft, Writing – review & editing, Project administration.

Data Availability

The datasets analyzed during the current study are not publicly available due to institutional review board restrictions but are available from the corresponding author upon reasonable request.

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Conflicts of Interest

The authors declare that there are no conflicts of interest.

Ethical Approval

This study was approved by the Institutional Review Board at the University of Kentucky (protocol number: 56488) and was conducted in accordance with the guidelines of the Declaration of Helsinki.

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Effects of a Heated Vibration Massage Pad on Horses: Randomized, Blinded Measures of Mechanical Nociception, Behavior, and Spinal and Limb Kinematics

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Abstract

Therapy devices are widely marketed to horse owners, claiming to improve well-being, support musculoskeletal function, and aid injury rehabilitation, though many claims lack scientific evidence. This study evaluated the immediate (part A) and four-week (part B) effects of a heated vibration massage pad applied to the thoracic epaxial region on mechanical nociceptive threshold (MNT), behavior, and kinematics of horses. A randomized, blinded design was employed with a convenience sample of 10 riding horses in treatment and control groups. Inertial motion sensors and limb markers captured kinematic data, behavior was analyzed using EquiFACS, and MNT was measured using pressure algometry. Immediately (part A) following application of the heated vibration massage pad, there were no significant changes in MNT, behavior, or dorso-ventral range of motion at the poll, wither, pelvis, or tuber coxae during walk or trot, nor in minimum difference, maximum difference, and range of motion at the poll, wither, and pelvis in trot, in the treatment or the control group (all $P > 0.05$). Similarly, stride length and duration in walk remained unchanged. However, in trot, the treatment group exhibited minor reductions in stride length ($P = 0.025$, $d = 0.2$) and hindlimb retraction ($P = 0.005$, $d = 0.5$), with increased stride duration ($P = 0.044$, $d = -0.17$). After four weeks of regular use (part B), the treatment group showed significant increases in stride length during trot ($309.8 \text{ cm} \pm 37.8$ vs. $334.4 \text{ cm} \pm 35.1$, $P = 0.017$, $d = 1.38$) as well as increased forelimb retraction, hindlimb protraction, and retraction. While immediate effects were negligible, consistent use of the heated vibration massage pad may enhance limb kinematics, suggesting its potential as a convenient addition to maintenance regimes for riding horses.

Keywords

Equine; therapy; therapeutic devices; vibration; locomotion

1. Introduction

Horse riders, owners, and trainers are responsible for the management of their horses and have a duty of care to engage in practices to optimize equine health and welfare [1]. As in human sport, horses commonly acquire musculoskeletal injuries, such as back pain and soft tissue injuries, that can result in reduced performance and lameness [2]. Although these conditions should be assessed and managed by the correct professional [3], advances in technology have led to therapy devices becoming increasingly accessible and

a popular choice for equine carers, providing a non-invasive and cost-effective therapy device. Devices are generally marketed directly to horse owners with suggestions regarding improvements of well-being, assisting musculoskeletal function, and supporting injury rehabilitation [4]. In human medicine, the use of vibration massage devices has become more popular in the management of musculoskeletal conditions [5], and this trend has extended into equine practice, where such devices are now being adopted based on anecdotal reports of improved muscle relaxation and recovery,

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despite a current lack of robust scientific evidence supporting their efficacy in horses.

The use of massage therapy has been well documented throughout human and veterinary literature and continues to be cited as one of the most popular alternative therapies to provide significant benefits to the treatment and maintenance of the musculoskeletal system [6,7]. Massage involves the application of pressure through movement of soft tissue and has been suggested to elicit an array of positive and therapeutic responses across species, including relaxation, pain reduction, and range of movement and performance improvements [8–10]. Such responses are demonstrated through behavioral, physiological, and biomechanical observations, suggested to stem from increasing parasympathetic activity when the appropriate pressure is applied [10,11].

Manufacturer claims suggest vibration massage improves performance by increasing flexibility and reducing musculoskeletal pain. A blinded controlled study investigating the effects of a vibration massage device applied to the horse's back concluded that there were improvements in thoracolumbar kinematics following use of the device [4]. However, this was a one-off treatment, and it was suggested that further research on longer-term effects was needed. The effect of vibration massage on the stress perception of domestic horses has been examined [12], and although not a targeted regional treatment, whole-body vibration has been shown to increase thoracolumbar epaxial muscle activation [13]. Two further non-peer-reviewed studies have shown improvement in stride length and limb range of motion [14,15]. However, to date, claims for outcomes resulting from the use of electronic vibration massage pads are unsupported in the literature.

While massage therapy has increased in popularity, thermal therapy, such as heat therapy, has also slowly increased in popularity, with similar positive and therapeutic responses reported, including an increase in local circulation [16], leading to muscle relaxation and extensibility [17]. Superficial heat therapy, the application of heat to the skin to affect the soft tissues, has been used as an adjunctive treatment of musculoskeletal conditions [18–21] with physiological benefits documented including improved circulation, allowing greater tissue oxygenation and extensibility, thus reducing muscle spasm and tension to promote relaxation of muscles and reduced joint stiffness [7,17,20]. In addition, prolonged deep heat application has been reported to activate thermoreceptors on the skin, which initiate a neural response that reduces nociception via the pain-gating system [7,22]. The increased nociceptive threshold of nerves and muscle spindles decreases the perception of pain [23] and is an effective method for pain management. Previous research has documented that the most profound physiological effects of superficial heat application occur when tissue temperatures are raised to between 40 °C and 45 °C; however, temperatures above 45 °C may potentially result in tissue damage and pain [24]. Due to these reported physiological benefits, electronic heated pads have therefore been deemed a useful therapy adjunct in equine maintenance and rehabilitation therapy [25].

With both massage therapy and heat therapy demonstrating positive and therapeutic effects when applied separately, it could be suggested that when applied together, they

also produce positive and therapeutic effects, if not similar, then superior results. Both massage and heat therapy are becoming increasingly utilized and available within equine rehabilitation [18]; however, the volume of literature to directly support the claims promoted by many of the device manufacturers within the equine industry continues to be very limited, often with poor methodology, small sample sizes and reliance on anecdotal evidence [12]. This underlines the need for research with well-designed methodologies to bridge the gap between proclaimed device benefits and the current research, reducing speculation within the industry.

The aim of the study was to investigate the short- and longer-term effects of a heated vibration massage pad placed over the thoracic epaxial region. It was hypothesized that the treatment intervention would show a significant difference in mechanical nociceptive threshold, behavior, spinal, and limb kinematics, pre- and post-intervention, when compared to the control intervention.

2. Methods

Ethical approval was obtained from the Hartpury University Ethics Committee prior to the start of the study (ETHICS2022-73; ETHICS2023-94).

2.1. Experimental Design

Two crossover design studies were conducted, with horses randomly assigned to an experimental intervention group (control or treatment), followed by a two-week washout period, and then undertaking the alternate intervention, to minimize the risk of confounding variables and selection bias. Two individual groups of horses were studied, and the subsequent methods and results refer to part A, which studied immediate same-day effects on Mechanical Nociceptive Threshold (MNT), behavior, and kinematics, and part B, which studied the effects of the heated massage pad being applied six times per week for four weeks on limb kinematics. Blinding of group allocation was maintained for the researchers throughout the data collection and initial analysis period.

2.2. Experimental Population

A sample size of 10 was calculated for each experimental group (standard power: alpha = 0.05, beta = 0.8, and using a Cohen's effect size of 1.0). In part A, a convenience sample of 10 mixed-breed riding horses (mean $\pm$ SD, age 9 $\pm$ 3 years, wither height 159 $\pm$ 3 cm, six geldings, four mares) was used in the study, and all horses were housed at the same facility, Hartpury College and University. In part B, a convenience sample of different horses from a livery yard was used, and a total of 11 leisure horses were recruited (mean $\pm$ SD, age 12.1 $\pm$ 4 years, wither height 152 $\pm$ 12 cm, six geldings, five mares). Participation was voluntary, and owners gave informed consent for their horses to be used, and they could withdraw their horse at any point of the study up to data analysis.

Subjects received a pre-assessment physiotherapy palpation and gait assessment (in-hand walk and trot in a straight line on a riding surface) prior to inclusion in the study, assessed by a single independent Veterinary Physiotherapist (registered with the Association of Chartered Physiotherapists in Animal Therapy). Horses who had any contraindications to massage, showed signs of back pain and/or epaxial

hypertonicity ($>2/5$ palpation score; [26]), were classed as lame ($\geq 2/5$ AAEP score; [27]) or who had received analgesics in the preceding seven days prior to the study, or during the study, were excluded from participation.

For part A, all horses had carried out their normal exercise duties the day preceding the study, and on the day of the study, prior to data collection, all horses were stabled overnight and had not been exercised. For part B, the pad application was completed before exercise, or at least four hours post-exercise, and these horses were kept in a consistent turnout and exercise routine throughout the intervention and control periods of the study. In both parts of the study, the participants were fitted with the heated vibration massage pad (Heatsense, Equilibrium Products Ltd, Aylesbury, UK) over the thoracolumbar region for 30 minutes. The dimensions of the pad were 90×40 cm and 75×40 cm, dorsally and ventrally, respectively, with a 5 cm height variation of the pad moving caudally (Figure 1).

The massage motors had three vibration frequency settings: low (17.1 Hz), medium (34.3 Hz), and high (51.4 Hz), all $\pm 10\%$, and were set to the medium setting for this study. There were three massage motors on each side, six in total, positioned to target the thoracolumbar epaxial musculature. The inbuilt thermotherapy setting was pre-set by the manufacturer at 42°C for the first 15 minutes, located bilaterally in the caudal 15–20 cm of the pad, with a gel element directly underlying. Once 15 minutes had passed, the thermotherapy element automatically turned off, while the massage element continued for the full 30-minute treatment time.

Participants receiving the control treatment had the same pad fitted to the thoracolumbar region for 30 minutes, but the pad remained switched off, so no treatment was

applied, and during both interventions, each horse was either tied up in a stable with a lead rope and head collar or held by their owner.

2.3. Part A: Mechanical Nociceptive Threshold (MNT)

Pressure algometry (PA; FDX50; Wagner Instruments, CT, USA) testing was carried out by an ACPAT Veterinary Physiotherapist who was blinded to the grouping of the horses pre- and post-treatment or control intervention to analyze MNT. Testing was located to the caudal trapezius and longissimus dorsi muscles, 10 cm lateral to the T8, T14, T18, and L3 dorsal spinous processes, bilaterally [2,26]. Test locations were determined based on the pad coverage and because the trapezius and *longissimus dorsi* muscles are common areas of tension in the horse [19].

The test location was marked using 1 cm^2 of hypoallergenic kinesiotape at 9 cm lateral from the aforementioned dorsal spinous processes and remained in place throughout treatment and data collection to ensure test location reliability [26]. At each site, three consecutive PA measurements at 3–4-second intervals were recorded, and an average was calculated for each site. Initial contact of the PA to the horse's skin was held for two seconds prior to pressure application, to reduce the likelihood of misinterpreting a startle response as a painful reaction [28].

Each PA measurement was applied at a constant speed, perpendicularly to the horse's skin, and was released at the first sign of a behavioral or physical avoidance reaction, e.g., muscle fasciculation, spinal movement, stepping away, or signs of equine pain face [29,30]. The value at the time of reaction was recorded.

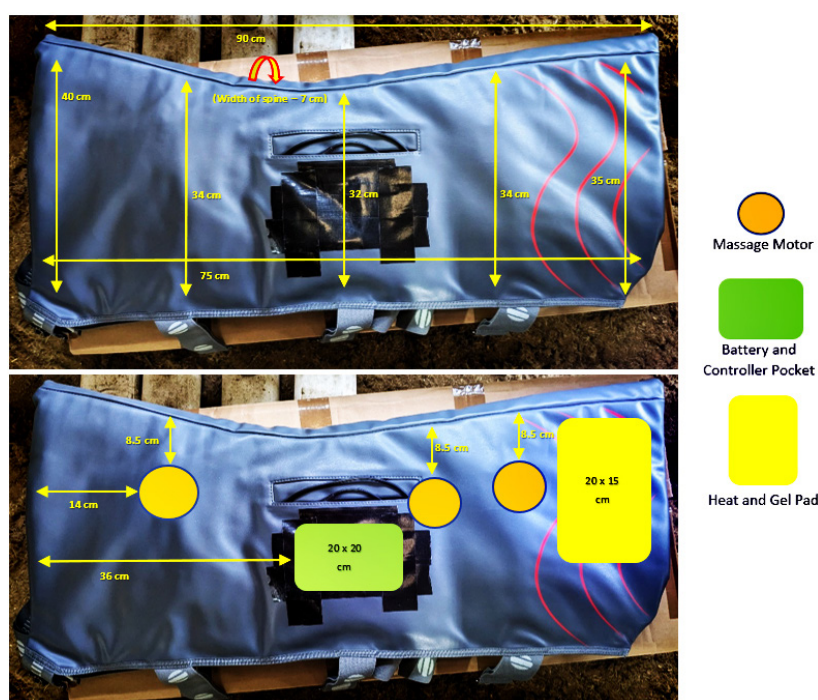


Figure 1: The heated massage pad and dimensions, showing the location of massage motors and heated zones.

2.4. Part A: Behaviour

To maintain standardization, during the treatments, one testing stall was used for the duration of the study. When receiving treatment, participants were tied up with their bridles and head collars on and were not allowed to eat for the duration of the analysis, based on the need to observe facial expressions.

For both experimental and control treatments, a video camera (60 frames/s, full HD/1080p) was set up on a tripod within the stall to capture video footage, with the horse's head and neck in frame. Video recording started after the pad was positioned on the horse, and recorded for five minutes pre-treatment, for the 30-minute treatment duration, and for five minutes post-treatment. Recordings were reviewed after each session of data collection and were muted to maintain researcher blinding.

Behavior analysis, by an EquiFACS-certified coder, used a scan sampling technique whereby behaviors were observed for 10 seconds at one-minute intervals for the duration of the pre-, during, and post-treatment recordings using an ethogram supported by the EquiFACS [31]. Frequency of behaviors (FoB) within each 10-second observation was reported and used for data analysis. To observe whether there was a trend in FoB while receiving treatment, during analysis, the 30-minute treatment duration was also split into 10-minute segments. Behaviors were selected and grouped into 'positive' and 'negative' within the ethogram (Table 1), based on research suggesting their indication of relaxation or stress, respectively [32,33].

2.5. Kinematic Parameters

For both the treatment and control groups, data were collected pre- and post-intervention (part A: after thirty minutes; part B: after four weeks), and the protocol utilized the same environment, handling equipment (bridle or headcollar), arena surface, and equine-specific handler for both data collection episodes. Horses were trotted in hand by their owners for 20 m on a soft surface which had clear open ends. Four trials were carried out in walk and trot; only straight motion cycles were included in the analysis. If a horse lost straightness, altered its gait, or increased or decreased its speed, the trial was repeated.

The horses were allowed to walk and trot at their preferred speed, during which laser-activated timers placed at the start and finish of the experimental track recorded the horses' speed [34]. Gait speeds differing by more than 0.2 m/s from the first valid run were eliminated and repeated until each subject performed the required number of passes (left to right) to gain 8 total passes (4 walk, 4 trot).

A video camera (iPhone 12) was placed at the center of the experimental track (a straight 2m × 25m area) on a free-standing tripod. Data were collected from the right side of the horse at 4K resolution, 60 fps, using a 10m field of view. The camera was positioned 7.2m from the nearest edge of the experimental track at the center of the field of view.

Eleven dome-shaped, 30mm diameter surface markers were positioned at pre-determined locations using double-sided tape by a single researcher, according to palpable surface landmarks [35] on the right side of the horse (Figure 2). Video recording images were analyzed using a digital image annotation tool designed for sports analysis (Kinovea version 0.9.5, 2022).

Table 1: The ethogram and indications of behavior with facial code associations.

Behavior	Definition	Indication	EquiFACS facial expression
Head lowered	Nose lower than withers between the abdominal line and carpus	Relaxed (+)	AD54: Head lowered
Ears relaxed or scanning	Ears moving back and forth at varying speeds	Relaxed (+)	Neutral/EAD101: Ears relaxed or scanning
Relaxed eyes	Relaxed eyelids with eyes open or closed. May include slow blinking (eye closure of >1 second)	Relaxed (+)	AU143: Eye closure
Licking and chewing	Tongue extended and retracted into the mouth, accompanied by teeth mashing together and jaw stretched in a horizontal motion to the right and left in a slow, steady motion	Relaxed (+)	AD81: Licking and chewing
Relaxed lower lip or yawning	Lower lip is visibly relaxed, or the mouth slowly opens, and upper and lower jaws are moved back and forth on a horizontal axis	Relaxed (+)	AD160/AD76: Lower lip is relaxed or yawning
Head raised	Nose above withers	Stressed (–)	AD53: Head raised
Repetitive head movement	A repeated, relatively invariant sequence of movements with no obvious function, including movements such as shaking, nodding, bobbing, and/or circling of the head	Stressed (–)	AD84/AD85: Repetitive head movement
Flattened ears	The ears are pulled caudally	Stressed (–)	EAD103: Ears flattened back
Eyes alert	The eyes are wide and may have the white sclera visible	Stressed (–)	AD1: Eye white increase
Nostril dilation	The aperture of the nostril is increased	Stressed (–)	AD38: Nostril dilation

2.6. Part A: Inertial Measurement Units

Horses were instrumented for part A prior to application of the heated massage pad with five inertial measurement units (IMUs) (XSens) using a validated sensor-based system (EquiGait Ltd) [36,37]. These were attached over the poll, wither, the midline of the tuber sacrale, and the cranial aspect of the left and the right tuber coxae using double-sided sticky tape. The same individual applied each sensor throughout the study, and to reduce variability, sensors remained on the horse throughout. Sensor data were collected at 60 Hz per individual sensor channel and transmitted via a proprietary wireless data transmission protocol (XSens Technologies B.V., Enschede, the Netherlands) to a receiver station (Awinda, XSens) connected to a laptop computer running MTManager (XSens) software. Details on IMU specifications can be found elsewhere [4,18,36]. Displacement data were segmented into individual strides based on the vertical velocity of the sensors, and average values for the following kinematic variables were calculated over an average of 25 motion cycles in walk and 22 motion cycles in trot. Range of motion (maximum–minimum value over a stride cycle) at walk and trot, minimum difference (MnD; difference between the two minima in dorsoventral (z) displacement observed during the two diagonal stance phases of trot), and maximum difference (MxD; difference between the two maxima in dorsoventral (z) displacement observed after the two diagonal stance phases in trot) were extracted for analysis [38].

2.7. Part A: Limb Kinematic Data

Carpal angles were measured on the palmar aspect of the limb using markers 2, 3, and 4 and were measured at peak carpal extension at stance onset (as the toe made initial contact with the surface) and peak carpal flexion at mid-swing. Tarsal angles were measured on the dorsal aspect of the limb using markers 7, 8, and 9, and were measured at peak tarsal extension at lift-off (as the heel left the ground) and peak tarsal flexion at mid-swing. Peak flexion was defined as the smallest carpal or tarsal angle measured during mid-swing [39]. Peak protraction was defined as the frame in which the limb was maximally extended cranially, and peak retraction was defined as the frame in which the limb was maximally extended caudally [39], and was calculated relative to the vertical using either markers 2 and 5 for the forelimb (FL) or markers 7 and 10 for the hind limb (HL). Stride length was calculated in metres and determined from the calibrated known distance travelled for each experimental run, using marker 10 on the fetlock of consecutive whole hoof placements of the right hind limb, with an average calculated [34]. Similarly, stride duration, defined as the time for one complete gait cycle [40], was calculated using the same marker and whole right hind hoof placement, with total known duration divided by the number of strides to give the average stride duration [41]. Kinematic data for analysis were collected from a singular stride in the centre of the field of view per experimental run for each horse, totalling four per gait (4 walk, 4 trot) from those that fell within the individual subjects' standardized speed bracket [42].



Figure 2: Anatomical markers used for video data collection: (1) Tuber of the scapular spine; (2) Lateral epicondyle of the humerus, over the lateral collateral ligament of the elbow; (3) Distal aspect of the radius at the lateral styloid process; (4) proximal aspect of the metacarpus at the base of the 4th metacarpal bone; (5) distal aspect of the metacarpus over the lateral collateral ligament of the metacarpophalangeal joint; (6) lateral collateral ligament of the distal interphalangeal joint (designated coronary band marker); (7) proximal aspect of the tibia at the fibular head; (8) mid talus; (9) proximal aspect of the metatarsus at the base of the 4th metatarsal bone; (10) distal aspect of the metatarsus over the lateral collateral ligament of the metatarsophalangeal joint; (11) over the lateral collateral ligament of the distal interphalangeal joint.

2.8. Part B: Limb Kinematic Data

Stride length, forelimb protraction and retraction, and hindlimb protraction and retraction in trot were measured by video analysis using Kinovea video software. Stride length was calculated in centimeters (cm) and measured by the calibration of a known distance. A whole stride was measured using a marker on the coronary band of the hoof of the right forelimb. Maximum protraction was measured at the point at which the forelimb or hindlimb was maximally extended cranially, whereas maximum retraction was measured at the point at which the forelimb or hindlimb was maximally extended caudally [39,43].

2.9. Statistical Analysis

Inferential statistical analyses were performed in IBM SPSS Statistics (v. 29.0; IBM, Armonk, USA, 2022). All data were tested for normality using a Shapiro–Wilk test, and data were found to be both normally distributed and non-normally distributed. For behavior, MNT, and part A kinematic data, if the dataset was found to be normally distributed, a related (paired) samples t-test was used, with the mean and standard deviation (SD) reported. If the dataset was found to be nonparametric, a Wilcoxon matched-pairs test was used, with the median and interquartile range reported. For MNT data, a Friedman test with post hoc comparisons was used to test repeated measures. Data are presented as mean $\pm$ standard deviation unless otherwise stated, and results were considered significant if $P < 0.05$, with Cohen's d used to calculate effect size correlations for significant results.

3. Results

3.1. Part A: Mechanical Nociceptive Threshold (MNT)

MNT measurements for all 10 participants were compared pre- and post- each intervention and between groups, and are summarized in **Table 2**. Analysis of the average MNT at each test location showed no significant differences between pre- and post-intervention figures for any of the locations in both the treatment and the control conditions.

Additional statistical analyses sought to establish whether there were any significant differences between the three measurements at each location, for each horse, to determine whether horses became sensitized or habituated to consecutive testing. The three consecutive PA measurements at each site were compared and showed no significant differences in the experimental group measurements or post-treatment control group measurements. However, for the pre-treatment measurements in the control group, T18 had lower MNTs in the second and third tests (median = 18.25 N/cm² and 18.75 N/cm², respectively) compared to the first test (median = 23.5 N/cm², $\chi^2 = 9.1$, $P = 0.01$). Post hoc comparisons indicated that the significance was between the first and second measurement ($P = 0.04$) and the first and third measurement ($P < 0.001$). L3 also showed lower MNTs in the second and third tests (median = 17.75 N/cm² and 16.5 N/cm², respectively) compared to the first test (median = 21 N/cm², $\chi^2 = 6.24$, $P = 0.04$), with post hoc comparisons indicating that the significance was between the first and third measurement ($P = 0.04$).

3.2. Part A: Behavior

Nine participants' data per group were included in behavioral analysis, as one participant's data were lost in the control scenario, and one participant's data were lost in the experimental scenario. Analysis of behavior showed no significant differences between pre- and post-intervention positive behaviors for either the treatment or control groups (**Table 2**). However, in the control group, participants demonstrated fewer negative behaviors post-intervention (median = 8) than pre-intervention (median = 10, $T = 1$, $P = 0.02$). Analysis of the 10-minute segments during treatment showed no significant differences between the three timeframes.

3.3. Part A: Inertial Measurement Unit Data

Data sets were lost due to an IMU system error; therefore, eight horses' data were used for the intervention group, and nine horses' data for the control group in trot, in walk, and nine horses' data were obtained during both the treatment and control intervention groups in walk.

No significant differences were found in the dorsoventral range of motion at the poll, wither, pelvis, and the left and right tuber coxae pre- and post-treatment intervention and pre- and post-control intervention, or between the treatment and control intervention groups in walk.

No significant differences were found in minimum difference, maximum difference, and range of motion at the poll, wither, and pelvis pre- and post-treatment intervention and pre- and post-control intervention in trot.

3.4. Part A: Limb Kinematics Data

Data from all 10 equine participants who completed the study protocol were analyzed. No significant differences were found in the analysis of the baseline measures between the treatment and control groups for stride length at either walk or trot, for stride duration at either walk or trot, for FL or HL peak protraction at either walk or trot, for FL and HL peak retraction at either walk or trot, for tarsal peak flexion (PF) and extension (PE) at either walk or trot, or for carpal PF or PE at either walk or trot.

There was no significant difference between the pre- and post-intervention stride length measures in walk; however, there was a significant decrease in trot in the treatment group ($P = 0.025$, $d = 0.2$). In the comparison of the pre- and post-control conditions, there were no significant differences in stride length in walk or trot. A significant increase in stride duration in trot was observed for the treatment group ($P = 0.044$, $d = -0.17$). No significant differences were observed in the treatment group for stride duration in walk, or for either comparison of the pre- and post-control condition in walk or trot.

No significant changes were observed when analyzing pre- and post-intervention control and treatment data for FL or HL peak protraction. A significant reduction was observed for HL peak retraction in trot for horses following receipt of the treatment (pre $30.9^\circ \pm 2.6$, post $29.6^\circ \pm 3.2$, $P = 0.005$, $d = 0.5$). No additional significant differences were observed for FL peak retraction for either the control or treatment condition when analyzing pre- and post-intervention measurements.

Table 2: Differences between pre- and post-intervention scores in the control and treatment groups for mechanical nociceptive thresholds (MNTs) and behavior (L = left, R = right, IQR = interquartile range, + = positive, – = negative, FoB = frequency of behaviors, P -value < 0.05).

Parameter	Location; landmark/L or R		Control median $\pm$ IQR (N/cm ²)	Treatment median $\pm$ IQR (N/cm ²)	Statistical Sig. (2 d.p.)
Pressure algometry (MNTs)	T8	L	2.84 $\pm$ 13.96	–7.17 $\pm$ 16.5	T = 64; P = 0.13
		R	–1.33 $\pm$ 17.7	3.25 $\pm$ 22.71	
	T14	L	–1.25 $\pm$ 8.05	–0.5 $\pm$ 11.51	T = 132; P = 0.31
		R	–1.58 $\pm$ 7.46	2.42 $\pm$ 21.83	
	T18	L	–1.09 $\pm$ 13.29	–2.75 $\pm$ 9.17	T = 78.5; P = 0.32
		R	–1 $\pm$ 5.17	–2.08 $\pm$ 19.67	
	L3	L	–3.67 $\pm$ 8.59	1.92 $\pm$ 10.79	T = 121; P = 0.55
		R	1.75 $\pm$ 10.34	4.09 $\pm$ 22.88	
Parameter	Time	Behavior (+ or –)	Control Median $\pm$ IQR (FoB)	Treatment Median $\pm$ IQR (FoB)	Statistical Sig. (2 d.p.)
Behavior	Pre-Post	Negative	–3 $\pm$ 3	–3 $\pm$ 11	T = 14.5; P = 0.93
		Positive	4.5 $\pm$ 8	3 $\pm$ 7	T = 16; P = 0.78
	During	Negative	38 $\pm$ 35	60 $\pm$ 31	T = 43; P = 0.11
		Positive	46 $\pm$ 26	43.5 $\pm$ 22	T = 32.5; P = 0.61

No significant differences were observed between pre- and post-intervention control and treatment data sets for tarsal PF or PE at walk or trot. When analyzing pre- and post-intervention data sets within each condition (control and treatment), a significant reduction (median (IQR); pre 176.8° (5.8), post 175.4° (6.7), P = 0.043, d = 0.2) was observed for carpal PE in trot for horses following the treatment intervention, compared with their pre-intervention baseline measurement. No significant difference was observed under the same experimental conditions in walk (P = 0.80) for carpal PE.

3.5. Part B: Limb Kinematic Data

At the start of the study, there were no statistically significant differences between the treatment and control groups for stride length in trot (control 322.0 cm $\pm$ 41.2 vs. treatment 309.8 cm $\pm$ 37.8), hindlimb protraction (control 5.1° $\pm$ 2.0 vs. treatment 4.6° $\pm$ 1.7), hindlimb retraction (control 23.8° $\pm$ 2.5 vs. treatment 23.3° $\pm$ 2.5), forelimb protraction (control 19.1° $\pm$ 2.6 vs. treatment 19.3° $\pm$ 3.41), or forelimb peak retraction (12.1° $\pm$ 3.1 vs. 12.3° $\pm$ 3.3).

At the end of the four weeks, there was a significant difference in mean stride length between the groups (control 320.2 cm $\pm$ 41.9 vs. treatment 334.4 cm $\pm$ 35.2, P = 0.007, d = –0.4). There was no significant change in stride length in the control group (322.0 cm $\pm$ 41.2 vs. 320.2 cm $\pm$ 41.9); however, there was a difference in the treatment group (309.8 cm $\pm$ 37.8 vs. 334.4 cm $\pm$ 35.1, P = 0.017, d = 1.38) (Figure 3).

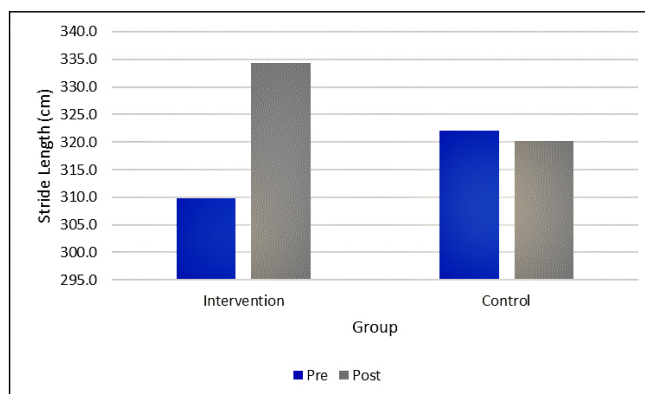


Figure 3: Stride length (cm) at the pre- and post-intervention measures in the control and treatment groups.

In the control group trial, there was a significant decrease in hindlimb protraction (5.1° $\pm$ 2.0 vs. 5.0° $\pm$ 2.0, P = 0.038), whereas in the treatment group trial, there was an increase over the four weeks (4.6° $\pm$ 1.7 vs. 6.9° $\pm$ 2.6: P = 0.003). Hindlimb retraction was significantly different between the control and treatment groups at the end of four weeks (23.5° $\pm$ 2.6 vs. 26.0° $\pm$ 3.5, P = 0.007). In the control group, there were no significant changes over time (23.8° $\pm$ 2.5 vs. 23.5° $\pm$ 2.6, P = 0.062); however, in the treatment group, there was a significant increase of 2.7° $\pm$ 3.0 (23.3° $\pm$ 2.5 vs. 26.0° $\pm$ 3.5, P = 0.017).

Forelimb protraction increased from 19.3° $\pm$ 3.4 to 20.1° $\pm$ 2.8 for the treatment group and from 12.1° $\pm$ 3.1 to 12.4° $\pm$ 3.1 in the control group; however, neither of these differences was statistically significant.

Forelimb retraction was statistically significantly different between the control and treatment groups at the end of four weeks ($12.4^\circ \pm 3.04$ vs. $14.5^\circ \pm 3.17$, $P = 0.006$). In the control group, there was a non-significant increase of $0.4^\circ \pm 1.0$ in forelimb retraction, and in the treatment group, there was an increase of $2.2^\circ \pm 2.1$ ($12.3^\circ \pm 3.24$ vs. $14.5^\circ \pm 3.17$, $P = 0.009$).

4. Discussion

The aim of this study was to investigate the effects of a heated massage pad on equine thoracolumbar MNTs, behavior, spinal motion, and limb kinematics. Based on the current literature, it was hypothesized that the pad may positively influence these parameters. In the short term, results suggest that within the sample used, the pad had no significant effect on thoracolumbar MNTs, behavior, or spinal motion. There were changes in trot for stride length (reduced), stride duration (increased), and hindlimb retraction (reduced) after 30 minutes of treatment. However, with regular use over a period of four weeks in the second group of horses, there were significant increases in stride length, forelimb peak retraction, hindlimb peak retraction, and hindlimb peak protraction.

4.1. Part A: Mechanical Nociceptive Threshold

The pressure algometer (PA) has been consistently reported as a repeatable measurement tool for quantifying pain and targeting MNTs within testing [30,44]. Given that massage and heat are reported to impact mechanoreceptors and nociceptors, it was considered an appropriate outcome measure for use in the present study. However, a reported limitation of PA is that repeated use may increase sensitization of the area [30]; however, ; however neither was observed for either group within this study.

When analyzing MNTs within the present study's healthy equine sample, the comparison to previously reported normal values seemed noteworthy. The present study's baseline values showed that the sample entered the study with MNT values much lower than other reported normal samples; at L3, the present study's average MNT was 20.85 N/cm^2 , whereas values of 51.9 N/cm^2 and 142.2 N/cm^2 have been reported in [30,45], respectively. All studies followed parallel protocols and endpoints of PA testing and included samples of sound, healthy horses of similar ages, although breeds varied between studies. Differences in tester experience with behavior recognition between studies are not known; therefore, it may be postulated whether the tester's sensitivity to behavioral avoidance signs differed between studies and contributed to differences in reported normal values. Future research on the pad could include additional, comparable outcome measures, such as palpation scoring [26,44].

4.2. Part A: Behavior

The EquiFACS coding system was used to give an objective foundation to a subjective field of study [46], categorizing the codes and behaviors into 'positive' and 'negative' to distinguish whether participants were undergoing a pleasant or unpleasant experience. Categorization was based on research indicating such behaviors could be signs of relaxation or stress, respectively [32,33]. Three of the participants in the present study demonstrated excessive licking and chewing throughout recordings of both the control and experimental treatments, and licking and chewing were categorized as a

'positive' behavior given its association with stress relief, relaxation, and a shift from sympathetic to parasympathetic activity [32,47]. However, it was suggested that licking and chewing could be associated with a negative affective state in horses when presented alongside agitated behaviors, such as ears back, stepping away, and tail swishing [48–50]. Given the ambiguity and varying scenarios in which licking and chewing have been presented within the literature, and the conflicting conclusions drawn from these scenarios, it would be unwise to conclude that the behavior was definitively positive or negative within the present study. Instead, it further highlights the need to analyze whole-horse behavior holistically to ascertain a more accurate affective state. In part B, the device was applied to each horse in the treatment group by their owners, and due to the risk of bias in recording behavioral responses, these data were not collected for analysis.

4.3. Part A: Inertial Measurement Unit Data

This study found no differences in the vertical displacement range of motion between pre- and post-measures in either group after 30 minutes. Using a similar methodology with IMUs, it was found that an increase in range of motion at the wither in a vertical direction and an additional increase in range of motion in the 13th thoracic segment in a medio-lateral direction [4]. The differences in vibration frequency and intensity between the unit used in this study compared with [4] are not known, and therefore, repeating IMU measurements before and after the application of the pad, using the different settings, may result in a different outcome. Knowing which frequency and intensity, i.e., what the dose-response is, would be useful when recommending the use of the pad to aid training or rehabilitation of an injured horse.

4.4. Part A: Limb Kinematic Data

Differences were observed in the analysis of the pre- and post-difference values compared between the intervention and control group data sets, for stride length and stride duration. The literature reports that even a slight change in the horse's stride length can have a positive influence on desired gait patterns, aiding peak performance [41]. Trot stride length was observed to significantly decrease, coinciding with a significant decrease in hindlimb peak retraction and carpal peak extension, whereas stride duration significantly increased in trot post-intervention. This potentially implies that greater time (s/stride) was taken to cover a shorter distance (m/stride) during a recorded stride. It could be postulated that this may be due to an increase in stride collection, reducing the longitudinal distance traveled per stride. However, dorsoventral displacement of the IMUs did not show any significant differences, and when considering the effect sizes, these statistically significant results can be considered not clinically relevant [51].

4.5. Part B: Limb Kinematic Data

This part of the study did not investigate stride duration or velocity, nor specific joint ROM; however, stride length was found to have increased significantly by 24.7 cm following treatment. A proposed explanation for the increased stride length could be the improvement in hindlimb protraction and retraction, which would increase the overall distance covered and therefore propulsion. Hindlimbs often have a higher peak propulsive force and a larger propulsive impulse

than forelimbs, due to large muscle groups such as the hamstrings creating large forces [52].

Research into the carryover of physiological effects of massage and heat is limited, but it is thought that the effects can last anywhere from a few hours to a few days in humans [10] and horses [53], suggesting that the effects do not tend to last long term. There was no effect on MNTs after 30 minutes, but when the pad was used on a regular basis, the accumulation of effects may result in MNT changes. The kinematic results of this study support the theory of longer-term benefit, and it is more likely that a pad will be used on a consistent basis over a longer period by owners as part of a maintenance regime, rather than as a single treatment.

Pad settings within the present study were pre-set by the manufacturer. This allowed for standardization and increased reliability across the treatment that all participants received. However, given that pain perception varies between individuals and pain is often quantified by testing pressure thresholds [54], it may be fair to consider that pressure preferences within massage may also vary between individuals. It was demonstrated that graduated massage significantly increased MNTs in the equine caudal thoracolumbar spine, with massage that was manually applied and adjusted according to the hypertonicity and myofascial pain presenting in each individual horse [55]. Such tailoring varied the duration of massage and muscles treated, whereas the present study kept these specifications the same throughout. One way in which the present study could have somewhat tailored treatment would have been to utilize the different frequencies available, rather than only using the medium setting (34.3 Hz), which was selected based on the suggestion that 30–50 Hz promotes muscle relaxation [11,56].

Though it is also notable that although the sample size met the power requirements, the 10 participants still represent a small sample, meaning a Type II error, where the null hypothesis is incorrectly accepted, was possible [57]. The sample was comprised of participants considered 'normal', in that they showed no signs of back pain (among other criteria), which may influence the transferability of results to those with back pain. Given that massage and heat have previously been suggested to dampen nociception [7,22,58], it may be fair to postulate whether a significant result would be seen if nociception was already stimulated, i.e., the more nociception is activated, the greater the nociceptive excitability there is to dampen. The same may be considered for relaxation; the more tense a horse is, the more effect of relaxation there is to gain. To test this hypothesis, future studies would need to include samples of normal, pain-free horses and horses with varying levels of back pain.

Kinematic data collection was obtained from the horses in hand and not ridden, to reduce the known effects from ridden assessments and the equipment used on the horse [59]; however, some effect from the handler may be inevitable. The handler may, to a varying degree, influence the head and neck positioning of the horse, indirectly influencing the back and therefore limb kinematics through head and neck

position [60,61]. The methodology of the current study attempted to minimize the effect of the handler through the use of the same handler for each horse during the experimental period, standardization of speed, and the test environment. To further improve data collection methodology and accuracy, the use of a high-speed camera, 3D motion analysis, and/or wearable sensor-type devices could be considered [62].

The study did not measure any physiological parameters to record changes in circulation, which is reported to increase with heat application [7,22]. Therefore, refuting previous suggestions that 40–45 °C heat application for 30 minutes elicits positive physiological responses (via a local increase in circulation) would be premature based on the present results. Further study could clarify the effect and level of contribution of both heat and massage treatment by comparing the heated massage pad with a non-heated massage pad and a control group. However, to gain a better understanding and further clarification of how temperature influences circulation, studies should include temperature monitoring and direct measurements of circulation.

5. Conclusions

In conclusion, the results from this study suggest that after four weeks of regular application of a heated vibration massage pad, there was an increase in stride length, forelimb retraction, and hindlimb protraction and retraction. Therefore, heated vibration massage pads may be a convenient method of improving limb kinematics when used as part of a maintenance regime on a regular basis, using the recommended manufacturer protocol of 30 minutes, six times per week. The present study was unable to report any short-term mechanical nociceptive threshold differences, behavioral changes, spinal locomotion, or gait symmetry effects when comparing pre- and post-treatment interventions with a control group. Significant changes in stride length, stride duration, and hindlimb retraction in trot were seen immediately post-treatment, but were numerically small, and therefore the cumulative effects appear to be more relevant to the horse.

While the heated vibration massage pad did not elicit any positive effects on the measurements taken for pain or behavior, it did not elicit negative effects either. Therefore, the results of the present study suggest that owners can use such devices on horses free of back pain, without detrimental effects, with the potential for longer-term benefits. Future studies could investigate habituation to the device and assess changes in behavioral responses with frequent use. As the pad combines heat and vibration massage, further work is needed to underpin the biological significance of vibration and heat therapy in the horse and to distinguish the clinical relevance for the industry.

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Authors' Contributions

G.T.: Conceptualization, Methodology, Formal analysis, Resources, Writing – original draft, Writing – review & editing, Project administration. N.B.: Methodology, Writing – review & editing. C.C.: Methodology. Z.D.: Methodology. E.J.: Methodology. F.B.: Methodology, Writing – review & editing. All authors have read and agreed to the published version of the manuscript.

Data Availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Conflicts of Interest

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

Ethical Approval

Ethical approval was obtained from the Hartpury University Ethics Committee prior to the start of the study (ETHICS2022-73; ETHICS2023-94).

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Assessing the Resilience Factor: A Preliminary Investigation into a Multifaceted Approach to Individual Parasite Control in Thoroughbred Foals

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Abstract

Standard equine management practices contribute to the high prevalence of strongyles and to the need for deworming. Horse performance can be evaluated by following early body development. This study aimed to determine the behavior and body growth associated with strongyle fecal egg count (FEC) in 25 Thoroughbred foals aged from birth to 10 months in southern Brazil. Body weight, withers height, and FEC were determined monthly, and foals' behavior/personality was recorded twice daily by resident veterinarians following standard welfare protocols. A generalized linear mixed model was used to analyze body growth and FEC variance. There was a high correlation between weight gain before six months of age and between height and age. Although males exhibited greater variability in weight and height, no statistically significant differences were observed between sexes ($P > 0.05$). There was no significant association between strongyle FEC and body weight or height in any animals. Descriptive behavioral analysis revealed that only four animals were treated based on behavior/personality alterations and clinical signs (i.e., abdominal discomfort). The data showed a null-to-weak correlation between FEC and the animals' age ($R^2 = -0.025$ for females and $R^2 = 0.168$ for males). Moreover, foals had a low (0.206) FEC repeatability coefficient for sex and age, while individual overdispersion indicated a high (3.919) value. This information is crucial when designing health protocols for horses, as the expected rise in FEC after treatment may indicate a new infection that accompanies a suppressive drug strategy. These preliminary data showed that foals experienced steady body growth, independent of FEC, allowing selective treatment to be guided by a combination of periodic clinical and analytical parasitological examinations. Furthermore, this study highlights the intrinsic influence of constant veterinary care and the protection of horse health as a strong component of farm resilience.

Keywords

Strongyle; body growth; yearlings; gastrointestinal infection; personality

1. Introduction

Standard management practices in horse breeding contribute to a high prevalence of parasitic infections during the first weeks of life. Helminth parasitism poses a significant challenge to equine health, as several species frequently

infect horses at this stage [1]. Among them, cyathostomins are the predominant helminths in Brazil [2]. High infection levels may cause clinical complications such as anemia, diarrhea, weight loss, peripheral edema, and even death [3]. These effects can compromise weight gain, as thousands of

encysted larvae may cover the intestinal mucosa, impairing nutrient absorption [4].

The development of parasitic disease depends on both exposure intensity and the host's immune and physiological responses. Genetic background, nutritional deficiencies, and chronic stress can increase susceptibility, leading to variability in individual responses to nematode infection [5]. The fecal egg count (FEC) test remains a valuable tool for monitoring egg shedding, selecting animals for treatment, and reducing pasture contamination [6]. FEC-based selective treatments also limit anthelmintic use and reduce selection pressure for resistance, as the parasite population in untreated animals remains unexposed to the drugs [7].

Animal welfare assessment in horses involves interactions among behavioral responses, stereotypies, and physiological indicators [8]. Parameters related to nutrition, health, behavior, and pain have been used as welfare indicators in naturally infected horses in southern Brazil. No significant relationship was observed between FEC and these indicators, suggesting that FEC alone is not a reliable measure of welfare when animals are maintained under adequate nutritional and health conditions [2].

Moreover, body size is primarily determined by genetics, and measurements taken during the early months of life reflect both genetic potential and expected adult size [9]. Nevertheless, environmental conditions, nutritional status, and sanitary management also influence growth rate. Studies have shown that suckling foal growth varies by birth month and season [10] and that between weaning and one year of age, seasonal factors consistently affect growth [11]. Body weight and withers height are central indicators of performance, and long-term monitoring of large foal populations has supported predictive models for the development of Thoroughbred foals in Brazil [12].

In most horse farms in Brazil, parasite control relies on the routine use of broad-spectrum anthelmintics due to their efficacy and safety. However, over the last two decades, widespread anthelmintic resistance in cyathostomins has been increasingly reported [13], including evidence from fecal egg count reduction tests (FECRT) indicating resistance to macrocyclic lactones [14–16]. In this context, selective therapy based on FEC monitoring has been proposed to manage parasitic infections while minimizing the development of drug resistance [17]. Clinical evaluation of body condition, weight gain, and withers height can complement FEC results to guide treatment decisions [18].

Thoroughbred breeders aim to prepare young horses for training and competition from approximately 30 months of age [10]. Economic assessments have demonstrated the feasibility of FEC-based targeted selective treatments [19]. Furthermore, bioeconomic analyses conducted under tropical conditions have revealed that treating only animals with the highest FEC values can reduce drug use without increasing the overall costs [20]. More recently, a 10-year field study

in Sweden demonstrated the practicality of such FEC-based control schemes, reinforcing their value for sustainable parasite management [17].

The literature integrating behavioral characteristics, clinical signs, body growth, and FEC to identify resilient foals under natural grazing conditions is currently limited. Additional physiological measurements (i.e., cortisol and hemogram) are still based on standard literature [8]. Therefore, the objective of this study was to determine whether FEC influences growth performance and behavior in naturally infected Thoroughbred foals, using an analytical decision-making protocol. This holistic methodology aligns with contemporary movements in veterinary parasitology, particularly in light of drug resistance and animal welfare [21].

2. Materials and Methods

2.1. Animal Management and Health Protocol

The study enrolled 25 newborn Thoroughbred foals from one farm in Tijucas do Sul, southern Brazil, born between July and December 2022. The animals were followed from January to October 2023. The area had native pasture in summer and *Lolium multiflorum* (ryegrass) in winter. Four regular pasture areas were used to accommodate 7 to 8 animals (animal density = 0.78), based on pasture quality and suitability, with no rotation or other grazing management practices. Animal distribution was considered by birth order, ensuring that males and females of similar ages were equally represented in each paddock to minimize animal and environmental bias. The animals were taken to the main stable twice daily to receive alfalfa (*Medicago sativa*) and 1.5 kg of a 16% protein mix. Individual pasture intake during free-grazing periods was not quantified.

The health protocol included monthly assessments of growth rate and weight gain. Foals' behavior was monitored daily using a standardized welfare protocol (Table 1) [2]. All observations were conducted by a trained resident veterinarian team as part of routine clinical management, allowing early identification of clinical or behavioral deviations potentially associated with parasitic infections. Behavioral sampling began with a 15-minute acclimation period and was conducted daily at 08:00 a.m. and 04:00 p.m. in the paddocks. Scan sampling was performed according to Table 1, starting approximately 5 meters from the foals and gradually approaching 2–3 meters for the human–animal approach test. During each session, behavioral indicators, including alertness, posture, responsiveness to the evaluator, avoidance, apathy, and uncommon events such as sweating, were documented in real time and summarized into frequency distributions to detect patterns or deviations indicative of welfare impairment. This integrated health and behavioral monitoring was used to support clinical decision-making, particularly regarding the need for antiparasitic treatment. Body condition score (BCS) was also evaluated monthly on a scale of 1 (emaciated) to 9 (heavily obese). Mares were not dewormed during gestation.

Table 1: Health and behavior parameters that were evaluated in the welfare protocol applied to 25 Thoroughbred foals from Tijucas do Sul, PR, Brazil.

Category	Behavior	Operational description	Interpretation/ relevance
General state/vigilance	Alert	Head and ears raised; attention to the evaluator	Adequate welfare
	Curiosity	Spontaneous approach toward the evaluator	Positive behavior
	Apathy	Low posture response, reduced movement	Compromised welfare
Posture and locomotion	Voluntary movement toward the gate	Coordinated movement during feeding times	Anticipatory behavior
	Immobility/Abnormal movement	Lack of movement when approached by a caretaker	Possible intestinal stress
Human interaction	Response test (2–3 m)	Slow movement toward or away from the evaluator	Tolerance, interest, or avoidance of humans
	Interest/approach	Voluntary approach toward the evaluator	Positive welfare
	Avoidance	Moving away from humans	Signs of discomfort
Social interaction	Group play	Jumping, mutual touching, playful behavior	Common in foals, an indicator of vitality
	Synchronized running	Group movement in the same direction	Social behavior of foals
	Proximity to conspecifics	Remaining close to others, especially near fences	Normal social sign
	Social withdrawal	Foal remaining away from the group	Sign of possible discomfort or illness
Reactivity/handling	Responsiveness to touch	Remaining calm when touched by the evaluator	Behavior based on the AWIN protocol
	Avoidance in handling	Stepping back, escape from touch	Normal in foal development
Indicators of discomfort or pain	Lowered ears	Ears held backward for a period of time	Nonspecific sign of discomfort or pain
	Unusual sweating	Localized sweating outside exercise	A marker of stress, pain, or an uncommon event
	Reduced voluntary movement	Lack of response to stimuli, failure to move	Possible intestinal discomfort
Environmental exploration	Sniffing objects/people	Exploration of veterinarians, caretakers, or environmental elements	Healthy behavior

2.2. Evaluation of Body Development and Coproparasitological Testing

All animals were checked monthly using a scale (Lider, Araçatuba, Brazil) and a hippometer (WalMur, Montevideo, Uruguay) to monitor weight (kg) and height (cm), respectively [22]. Individual fecal samples were collected from the rectum of the animals and transported to the laboratory in styrofoam boxes for processing within 24 h. Individual coproparasitological examinations were performed using the modified Gordon & Whitlock [23] technique with a conversion factor of 25 [24]. Subsequently, a pooled fecal sample was used to harvest and identify third-stage infective larvae (L3). All analyses were performed in triplicate, with 50 larvae analyzed per repetition [25].

2.3. Climate Data

The National Institute of Meteorology (INMET, Brazil) provided the monthly climate data, including average temperature (°C) and precipitation (mm³), for the Tijucas do Sul region. The meteorological data were obtained from the CURITIBA-A807 weather station, located in Curitiba, PR, Brazil.

2.4. Statistical Analysis

The power of the test was adjusted to 35 births on one farm, as horse management adopted a behavior-based protocol. Therefore, the sample size ($n = 25$) was determined based on a 90% confidence level, with a 10% margin of error. The value of n was obtained from the finite population equation (1) represented below, with z defined as 1.645 for 90% confidence, p conservatively defined as 0.50 in the absence of previous

prevalence data, $e = 0.10$ as the absolute precision, and $N = 35$ representing the number of eligible births on the farm; the denominator term applies the finite population correction.

$$\text{Sample Size} = \frac{\frac{z^2 \times p(1-p)}{e^2}}{1 + \frac{z^2 \times p(1-p)}{e^2 N}} \quad (1)$$

The weight and height data of the animals were adjusted using the Generalized Linear Model (Proc-GLM) for a Normal (Gaussian) distribution. The nonparametric Spearman test was used to assess the correlation between weight and height by age and by age and sex. The nonparametric Wilcoxon rank-sum test was used to compare males and females within each age group. Nonparametric tests were selected for correlation and group comparisons because preliminary diagnostic checks indicated that the weight and height data did not meet the assumptions of normality and homoscedasticity required by parametric methods. Since Spearman's rank correlation and the Wilcoxon rank-sum test do not assume normality, linearity, or normally distributed residuals, a log transformation was not applied. Linearity was evaluated only for the components analyzed using the Generalized Linear Model (Proc-GLM), for which residual diagnostic plots (residuals vs. fitted values and Q-Q plots) were examined to verify model adequacy. Spearman's correlation was used to assess monotonic associations rather than linear relationships, which eliminates the need to test for linearity. Statistical significance was set at a 5% level ($P < 0.05$). The median test was used to assess whether there was a statistically significant difference in median weight between the sexes.

For FEC data, three models were adjusted using the Zero-Inflated Negative Binomial Regression Model methodology. FEC variability was partitioned among repeated measures for each individual, with the animal identifier (Animal ID) included as a random effect in the generalized linear mixed model (GLMM). This structure allowed the authors to account for temporal dependence among observations and to separately estimate the variance attributed to individual differences (between animals) and residual variance (within animals over time).

The repeatability analysis of fecal egg counts (FEC) was performed using a generalized linear mixed model (GLMM) with a Poisson error distribution and an overdispersion term, adopting a link-scale (latent-scale) approximation to decompose variance components. The 95% confidence intervals, standard errors, and repeatability estimates were obtained via parametric bootstrapping with 500 iterations. In contrast, the statistical significance of the variance components and repeatability coefficients was assessed using

the Likelihood Ratio Test (LRT). The association between treatment status and egg shedding was assessed using odds ratio analysis with a 95% confidence interval. A descriptive analysis was employed to examine welfare, monitor subtle changes in horse behavior, and detect uncommon events. The tested hypothesis evaluated whether the variances and repeatability coefficients for the animal groups and the overdispersion differed from zero. All statistical analyses were performed using R, version 4.4.0 (i386).

3. Results

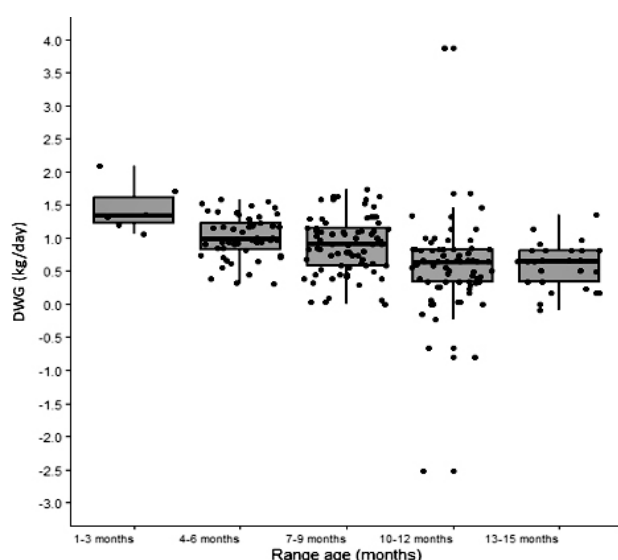
According to the behavior assessment (Table 2), foals displayed alertness, curiosity, and anticipatory behavior in 99.2% of observations, while positive human-directed exploratory behaviors were recorded in 82.0%. Social behaviors such as group play and proximity to conspecifics were frequently observed. In contrast, deviations indicative of potential welfare compromise occurred only 3.6% of the time, and behavioral changes directly associated with parasitic infection were identified in just four foals throughout the study period. Throughout all evaluations, the foals had BCS within the 4–6 range, considered appropriate for young animals, with overall stability across monthly measurements. Only two individuals were classified as underweight (BCS 3), slightly below the expected condition, during a single assessment, with no recurrence in subsequent weightings. No overweight animals were observed (data not shown).

Coprological analysis revealed a predominance (79.9%) of the *Strongylidae* superfamily, followed by *Parascaris spp.* (19.9%). Coproculture enabled the identification of L3 from various cyathostomin groups (A, B, C, D, and F), as well as *Posteriostrongylus* spp. and large strongyles, including *Triodontophorus* spp. and *Strongylus vulgaris*. Among the identified cyathostomins, type A (63%) and C (19.5%) were the most prevalent throughout the study. Considerable variation in parasite egg shedding was observed among individuals, with standard deviations of approximately 728 EPG for females and 628 EPG for males. The data reinforce the heterogeneous distribution of parasites in horses. Climate data also revealed a weak negative correlation between FEC and temperature ($r = -0.1482$). In contrast, a moderate positive correlation was observed between FEC and precipitation ($r = 0.4973$).

The animals demonstrated continuous body growth, reaching their peak at 15 months of age. It was observed that the average daily weight gain (DWG) varied across age groups. Animals aged 1–3 months showed the highest values (approximately 1.3 kg/day). For animals aged 13–15 months, the DWG dropped to 0.6 kg/day. Regarding variability, the 7–9-month age group showed the most significant variation in DWG (Figure 1).

Table 2: Ethogram-based quantitative summary of behavior of 25 Thoroughbred foals from Tijucas do Sul, PR, Brazil, monitored twice daily over 10 months. Percentage values represent the observations in which each behavior was recorded.

Category	Behavior	Observations	Obs. (%)	Notes/interpretation
General state	Alertness/curiosity	2× day	99.2%	Foals were alert and curious, indicating positive welfare
Posture	Voluntary movement	2× day	99.2%	Good voluntary movement toward the gate at feeding time; good anticipatory behavior
Human interaction	Approaching/exploratory behavior	2× day	82.0%	Positive interest in humans; good habituation to handling and human–animal interaction
Social interaction	Group play	Once daily	~70%*	Positive social/group behaviors, indicative of normal development and adequate welfare
Social interaction	Proximity to conspecifics	Once daily	≥80%*	Maintenance of proximity to other foals; normal affiliation
Deviation from normal	Welfare compromise signs	2× day	3.6%	Sporadic, associated with mild, transient intestinal discomfort during weaning or paddock changes
Associated with parasitism	Behavioral changes associated with parasitic infection	2× day	0.82%	Behavioral/clinical growth alterations linked to parasites

**Figure 1:** Boxplot of the average daily weight gain (DWG; kg/day) at different ages of 25 Thoroughbred foals from Tijucas do Sul, PR, Brazil. Boxes represent the interquartile range, horizontal lines indicate the median, whiskers show data dispersion ($1.5 \times \text{IQR}$), and dots represent outliers.

Greater body weight variability was observed in males than in females (**Figure 2a**). The minimum recorded weight was lower in females (102.0 kg) than in males (131.0 kg), whereas the maximum weight was higher in males (433.0 kg) than in females (422.0 kg). The relationship between body weight and sex was evaluated using the median test, yielding $Z = -1.0863$ and $P = 0.2773$, indicating no statistically significant difference. The minimum height observed was 112 cm for females and 119 cm for males, while the maximum heights were 151 cm and 153 cm, respectively (**Figure 2b**). The median test yielded $Z = -0.6718$ and $P = 0.5018$, indicating no significant difference between sexes.

Figure 3 shows the distribution of FEC across age groups. Animals aged 1–3 months presented the lowest FEC, indicating early infection, compared with the other categories. The highest counts were observed in the 4–6-month-old group. Moreover, two FEC peaks were identified in the 4–6-month age group, with the highest concentration reaching up to 100, while the second peak ranged from 1,400 to 2,200 FEC. Although animals in the 4–6-month age group showed higher FEC, they maintained greater DWG than older animals.

The body growth data did not reveal a significant association between strongyle FEC and body weight ($R^2 = 0.0235$) and height ($R^2 = 0.0209$). The distribution of FEC varied considerably among individuals, with 73.8% of the 183 records falling between 0.0 and 975 (min. = 0.0; max. = 3,750) (**Figure 4**). Only four foals, aged 10–12 months, were treated with a combination of ivermectin 1% and praziquantel 7.5%. The decision was based on clinical signs: liquid feces ($n = 2$), mild abdominal discomfort ($n = 2$), expected weight gain for age ($n = 1$), and the presence of cyathostomins in feces ($n = 2$). FEC was not used as a treatment criterion.

Considering a scenario in which animals are subjected to anthelmintic treatment based on high FEC, an OR analysis was performed to assess the likelihood of an animal being treated (True) or potentially treated based on different ranges. For animals with FEC between 0 and 100, the estimated OR was 0.404 (95% CI: 0.0577–1.4831; $P = 0.1919$), suggesting a likelihood of low FEC among treated animals (False) of approximately 60%. For high FEC values ($\geq 1,000$), the estimated OR was 0.0573 (95% CI). Therefore, the odds of a treated animal being in the high FEC group were only 5.7%.

Additionally, a repeatability analysis revealed consistency of FEC over time ($R^2 = 0.206$), indicating low to moderate within-individual consistency and high individual variability. Contributing to this, the variance associated with overdispersion was substantially high ($VO = 3.919$; $P < 0.001$),

suggesting that most of the observed FEC variability arises from random environmental factors and the aggregated nature of nematode infections, rather than from fixed group or age-level effects.

Two groups of animals were compared based on FEC. Group 1 (FEC 0–100) included 58 observations: 56 from unequivocally untreated animals and two from confirmed or possible

antiparasitic treatment. Group 2 (FEC $\geq 1,000$) included 69 observations: 53 were from untreated animals, and 16 from individuals with confirmed or suspected antiparasitic treatment. The final weights and heights were 300 kg and 142 cm for the low FEC group, and 310 kg and 141 cm for the high FEC group, respectively, showing no statistically significant differences ($P > 0.05$) between the FEC-extreme groups (data not shown).

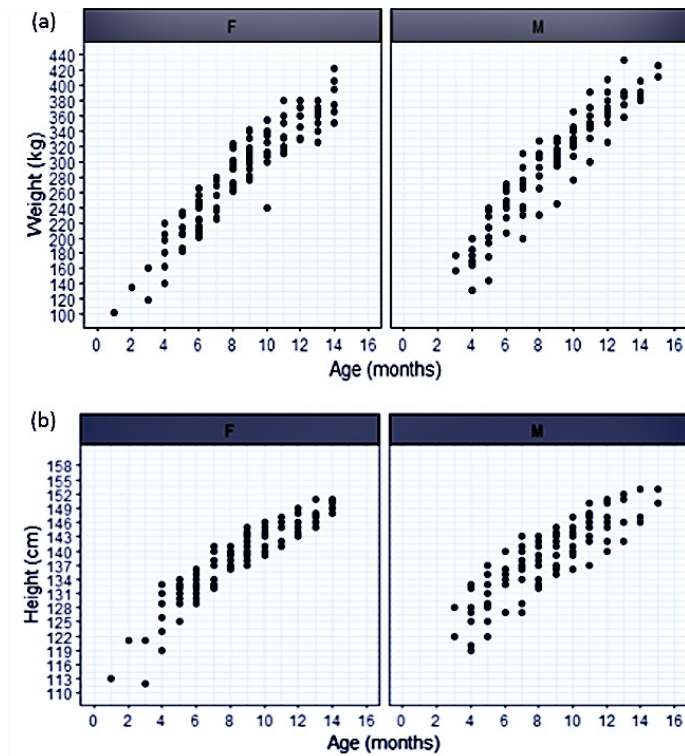


Figure 2: Body growth distribution of male (M) and female (F) Thoroughbred foals ($n = 25$) from Tijucas do Sul, PR, Brazil. (a) Body weight (kg) and (b) withers height (cm) by age (months). Each black dot represents an animal.

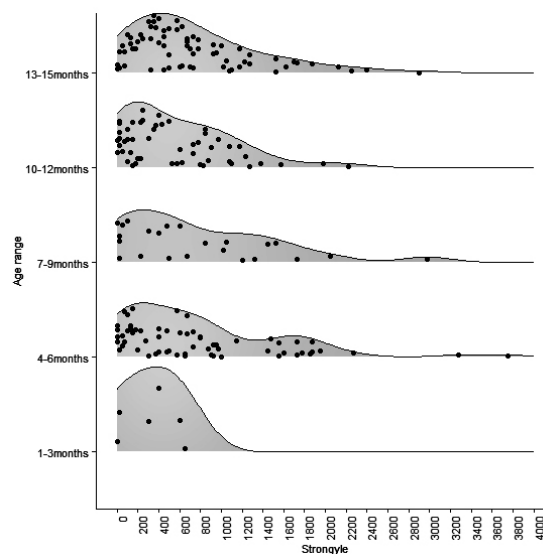


Figure 3: Density distribution of strongyle fecal egg counts of 25 Thoroughbred foals from Tijucas do Sul, PR, Brazil, at different ages. Black dots represent individual data points.

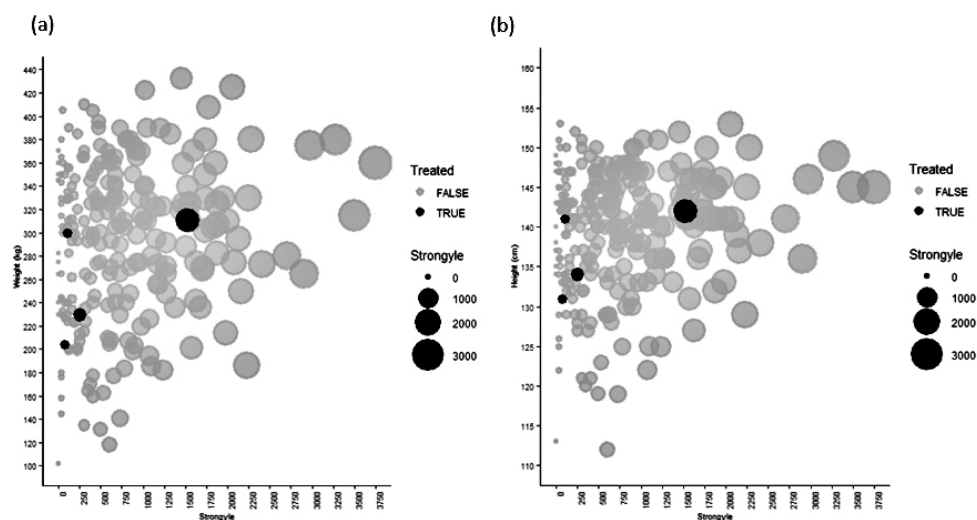


Figure 4: Distribution of strongyle fecal egg counts and (a) body weight (kg) and (b) withers height (cm) of 25 Thoroughbred foals from Tijucas do Sul, PR, Brazil. The size of the circles represents the strongyle egg count; black circles indicate treated animals.

4. Discussion

The behavioral consistency observed throughout the adopted conditions, characterized by high frequencies of alertness, curiosity, anticipatory responses, and positive human-directed interactions, indicates that gastrointestinal parasitism had a limited visible impact on the welfare of the foals. Previous evidence shows that behavioral deviations in naturally infected horses tend to be subtle and often insufficient to reliably differentiate animals with high and low parasite burdens in well-managed systems, which is consistent with the results found here [2]. In the present study, alterations such as apathy, social withdrawal, lowered ear position, and reduced voluntary movement were rare (<4%) and generally associated with transient episodes during weaning or following changes in grazing paddocks, rather than with consistent parasitic loads. The small number of animals showing behavioral changes directly attributable to parasitism (four foals) further supports that low to moderate strongyle exposure tends not to generate robust or observable welfare impairments in young animals.

These results are also consistent with studies demonstrating that indicators such as reduced responsiveness, abnormal posture, avoidance of human contact, and decreased social engagement arise primarily in contexts of significant physiological challenge, including pain or systemic illness, and not merely in cases of mild parasitic infection [26]. The low prevalence and low intensity of behavioral alterations observed in this study support this interpretation. Additionally, there is evidence that parasitic infections may trigger subclinical physiological changes, such as shifts in gut microbiota composition, before overt behavioral changes become detectable, suggesting that behavior may represent a late and relatively insensitive marker of early or acute parasitic stress [27].

The prevalence of *Strongylidae* and *Parascaris spp.* observed in this study follows the epidemiological pattern widely

described in horses. An extensive retrospective analysis conducted in Brazil, involving nearly 20,000 samples over 12 years, reported a prevalence of gastrointestinal helminths of 68.5%. Strongyles were responsible for most infections, and a significantly higher risk was observed in young animals during rainy periods. Mean FEC were 453.5 (± 717.6) for strongyles and 17.1 (± 147.1) for *Parascaris spp.* [13]. Similarly, a study in Thailand reported a 50.9% prevalence of strongylids, with an average of 445.7, and only 25.7% of horses showed values ≥ 200 [28]. Although some selective treatment regimens are based on FEC [17,20], our study did not use FEC for either predictive health or growth performance indicators.

In the present study, cyathostomin types A (63%) and C (19.5%) predominated, a distribution consistent with national and international reports, which show type A as the most frequent (50–75%), followed by types D and C, with regional variations. In Paraná, Brazil, type A accounted for 62% of samples, D for 25.3%, and C for 5.7%. Coproculture and L3 identification confirmed a stable parasitic fauna on the studied farms. This technique remains a practical and cost-effective tool for monitoring equine parasite communities and detecting selective pressures associated with anthelmintic use. Reduced biodiversity and predominance of type A may indicate emerging drug resistance [29].

Other larval types—B, E, F, G, *Gyaloccephalus capitatus*, and *Posteriostomum spp.*, were rare (<3%). These results align with previous studies [30], confirming that cyathostomin populations in horses are typically composed of a few dominant species [28,29]. The observed diversity reinforces the heterogeneous yet predictable nature of equine parasite communities, which are usually dominated by a few taxa, regardless of location or management. L3 characterization thus remains essential for understanding parasite ecology and for designing region-specific control programs [28–30].

The correlations found between FEC and climatic variables suggest that precipitation, in particular, may have influenced

parasite dynamics, although not sufficiently to establish strong predictive relationships or create a warning system. Ecological models show that humidity favors larval survival, whereas drought reduces persistence [5,28]. Nevertheless, such models do not fully capture the complexity of production systems, underscoring the need for management strategies tailored to local climatic conditions. Temperature and moisture significantly impact egg hatching and larval development, with optimal development occurring between 25 °C and 33 °C. In contrast, freezing or desiccation drastically reduces larval yield. L1 and L2 larvae are especially vulnerable, whereas L3 can persist for months within intact fecal pellets [5]. The retrospective Brazilian study reported that FEC for *Parascaris spp.* and strongyles varied seasonally, with higher values in summer and lower in winter, confirming the influence of climate on parasite dynamics [13]. The results of the present study align with this pattern, highlighting that climatic variables interact with nutritional and management factors, rather than acting in isolation. Integrating environmental and parasitological data is therefore essential for a comprehensive understanding of infection dynamics.

Simulation studies further indicate that climate and seasonality influence the development of anthelmintic resistance. Drug resistance evolved more rapidly when treatments are applied in the spring under temperate conditions, as surviving worms contaminated pastures throughout the entire grazing season. Conversely, selective treatment in early spring delayed the development of resistance in colder regions [31]. In subtropical areas, seasonality has a minor influence on the advantage of selective therapy. Collectively, these findings demonstrate that FEC must be interpreted within environmental and climatic contexts, as temperature and rainfall patterns significantly impact parasite survival, clinical expression, and the sustainability of control practices. We consider these epidemiological and seasonal factors to be critical for field clinicians who need to base their decisions on high and low parasite transmission rates.

Foals of both sexes showed progressive body growth. These results align with those observed in Thoroughbred foals [32] during the first 13 months [9]. Foals raised in Brazil averaged 397.8 kg and 150.6 cm at 18 months, consistent with other breed standards [12]. These findings are similar to those in Kentucky (USA), where Thoroughbred foals reached an average of 250 kg at 6 months (43% of adult weight) and 350 kg at 12 months (61%) [9]. Despite the use of suppressive antiparasitic treatment every 4–8 weeks in the above studies, body performance was comparable to that observed in the present results, with practically no anthelmintic use. Similar growth rates have also been reported in India [10].

Under natural infection and minimal deworming, nutritional management and animal welfare were found to be decisive in maintaining satisfactory performance. Free access to pasture and concentrate supplementation likely supported optimal growth. High-quality pasture in the spring has been shown to improve body development in horses [10]. In contrast, diets high in starch and low in fiber may predispose horses to metabolic disorders such as laminitis and insulin resistance, reinforcing the value of balanced nutrition [33].

The comparison between body development and FEC revealed that foals with high FEC (>1,000 EPG) achieved

expected growth rates, suggesting that natural infection did not negatively impact performance. These findings support the hypothesis that within the observed range, FEC did not affect growth performance, indicating that monthly weight and height can serve as complementary parameters in equine health assessments [12,13]. The OR analysis revealed that foals with high FEC were also less frequent among treated animals, demonstrating reduced infection risk in this group. However, treatments were primarily based on clinical signs, such as diarrhea or mild colic, rather than on fixed FEC thresholds. This contrasts with studies that used specific intervention limits—for instance, 200 EPG [17,34,35]. Monitoring studies show that selective treatment markedly reduced drug use in only 34.7% of horses when they reached the 200 thresholds [36]. In Sweden, national monitoring revealed that 59% of horses did not require treatment under FEC-based protocols [17]. Nevertheless, FEC may not accurately reflect actual parasite burdens, as host immunity and physiological regulation can also influence egg production [37].

Higher FEC values were recorded in foals aged 13–15 months, matching patterns observed elsewhere. In Kentucky, untreated foals around 12 months exhibited higher counts than younger ones [31]. An extensive Brazilian study confirmed that young horses (≤ 2 years old) shed three times as many eggs as adult horses [13]. Similarly, a German study found that the mean strongyle FEC was above 800 in foals and yearlings. In contrast, adults averaged below 200 EPG, confirming that young animals are major contributors to environmental contamination and herd transmission [31]. Although avoiding systematic treatment helps prevent drug resistance, failure to treat high-risk age groups may compromise welfare and increase pasture contamination. Therefore, a question has arisen regarding the adoption of behavior and clinical protocols for foals and how that would contribute to higher larval concentrations in subsequent seasons.

The adoption of behavioral/performance protocols for horses enabled a more precise understanding of the relationships among welfare and parasitism. In the present study, the farm protocol has been in place for the past six years, with no significant changes or adverse events. Thus, integrating these protocols improved the interpretation of host responses to parasitism and guided management strategies. From another perspective, the longer the protocol is applied, the more resilient and less at risk in terms of welfare [38] the herd will ultimately become.

It is known that larval concentration is regulated by biotic and abiotic factors. Thus, considering that eggs are degraded by fermentation and light exposure on pasture or ingested at different free-living stages, a considerable number of larvae are removed before reaching the infective stage. It is also assumed that behavior-based monitoring does not lead to a significant increase in transmission levels, as animals reach immune maturity at an earlier age. Therefore, a long-term study would be necessary to confirm this hypothesis, including data on farm management, immune-specific status [39] (validating for South America), climate, and seasonal conditions to determine the pattern of egg shedding

among untreated animals and, consequently, the available larval risk to young foals.

In the present study, only four animals were treated, compared with standard blank regimens with 45–60 days' intervals (150–170 doses/10 months) [40], representing a >97% reduction. In this sense, the identification of more tolerant hosts is also a positive outcome of the study. A recent genome-wide association study (GWAS) identified genomic regions associated with FEC in naturally infected adult and young Thoroughbreds. The data accounted for up to 2.86% of the additive genetic variance. Candidate genes, such as ABCC4 and CD180, were associated with immune functions, including dendritic cell migration and Toll-like receptor signaling, providing new genomic evidence that connects host immunity to parasite egg shedding and resilience [11]. Although preliminary, this is the first GWAS study to cover horse genomics and FEC as a risk factor in mares and their foals.

Beyond biological factors, economic considerations play a central role in sustainable management. Cost analyses of FEC-based protocols with a 200-EPG threshold indicate that three group screenings per year (February/March, June/July, and September/October) effectively guide treatments. Under such programs, only 16–20% of horses require treatment per screening, plus one mandatory moxidectin-praziquantel treatment in December. This season-based approach drastically reduces the number of treatments compared to suppressive regimens, while FEC-based therapy lowers costs by approximately 36.7% [41]. The protocol using behavioral and clinical interventions achieved a much greater reduction, with no compromise to horse health.

These outcomes align with reports of reduced drug use and costs [17,19]. The benefits of such approaches increase when parasite control is viewed holistically, taking into account environmental sustainability and animal welfare. Economic models show that selective treatments can cut anthelmintic costs by up to 80%, and simplified testing, such as pooled fecal analysis, may further reduce costs while maintaining effective control [42]. Environmentally, limiting chemical interventions reduces antiparasitic residues in soil and water, mitigating ecotoxic risks under the One Health framework [43]. In this sense, parasiticides can contaminate ecosystems and harm non-target species, making the reduction of their use critical.

From a welfare perspective, selective treatment reduces the frequency and duration of handling, causing less stress for the horses. It is known that horses exposed to stressors exhibit elevated fecal cortisol metabolite levels, with variations linked to transport, management, and environmental conditions [44]. The present data are sufficiently robust, as the animals belonged to the same breed and age category and were maintained under uniform environmental conditions and daily management. Although the protocol should be applied across other farm conditions and animal breeds, these findings support farm-specific programs that integrate behavior analysis, horse performance, and resilience to parasites.

5. Conclusion

A wide variation in fecal egg counts was observed among foals, yet no significant effect on body growth was detected under the present conditions. The consistent growth likely reflects the farm's high standards for nutritional and health management. These findings support an integrative approach to parasite control that considers both FEC and overall animal condition. Despite the limited sample size and study duration, this preliminary individualized decision-making assessment offers veterinarians and animal breeders valuable insights into resilience-based management strategies to promote sustainable equine health and welfare.

Authors' Contributions

E.P.: Conceptualization, literature review, data analysis, writing—original draft. I.R.N. and A.J.F.: Conceptualization, data analysis. E.P. and U.Y.: Literature review, critical review. M.B.M.: Validation, supervision, critical review, writing—review & editing, final approval of the manuscript.

Data Availability

All data analyzed in this study are available from the corresponding author upon reasonable request.

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Conflicts of Interest

The authors declare no commercial or financial conflicts of interest.

Ethical Approval

The project was approved by the Ethics Committee on the Use of Animals in the Agrarian Sector at the Federal University of Paraná (CEUA/UFPR); Approval No. 2014/026.

Declaration of Generative AI and AI-Assisted Technologies

The authors declare that no generative AI or AI-assisted technologies were used in the collection, analysis, or interpretation of data during the preparation of this manuscript.

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Horses for Courses: Identifying Coaching Capabilities and Contexts in Equestrian Coach Development Pathways

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Abstract

The British Equestrian Federation (BEF) aims to improve coaching quality by identifying essential capabilities within different participant contexts. This study focused on the performance development context, examining the specific coaching skills required to tailor coach education effectively. Seven expert performance development coaches (n = 5 females; n = 2 males), identified by the BEF, participated in semi-structured interviews. Data were analyzed using a grounded theory approach to identify key coaching capabilities. Findings highlighted two major themes. First, expert coaches are coaches with expertise and experience, and effective coaches are empowering, as coaching extends beyond technical and tactical instruction, enabling athletes to become autonomous. Coaches recognized the importance of influencing riders psychologically and emotionally, not just through skill instruction. Coaches are open-minded, as they actively seek transferable skills and value knowledge from expert coaching in other sports, viewing cross-disciplinary learning as beneficial to their development. Secondly, expert coaches are adaptable, working comfortably across multiple contexts rather than exclusively within performance development. They emphasized that most coaching capabilities are required in all contexts, albeit to varying degrees. The pathway to expertise requires a substantial base of declarative and procedural knowledge, alongside extensive coaching, training, and competitive experience. While findings align with broader coaching literature, differences emerged due to the unique nature of equestrian sport, particularly the rider–horse dynamic. Further research into other coaching contexts is needed to develop a holistic understanding, ensuring these findings inform coach education across the equestrian sector.

Keywords

Equestrian; horse riding; expert coach

1. Introduction

Equestrian sport presents a unique coaching environment, shaped by the complex triadic relationship between coach, rider, and horse [1]. Despite the sport's distinct characteristics, coach education and development models in equestrianism have often mirrored more traditional, 'instructor-style' frameworks, potentially overlooking the nuances of horse–human interaction and the diversity of equestrian disciplines [2]. As the landscape of coach development continues to evolve across sports, there is a growing recognition

of the need to tailor athlete-centered coaching pathways to better reflect specific contextual demands and the capabilities required within each setting.

In broader sports coaching literature, there has been a notable shift toward understanding coaching as a situated, relational, and dynamic practice. Contemporary research emphasizes the value of context-specific knowledge, interpersonal skills, and professional judgment in shaping effective coaching [3,4]. Models such as the Professional Judgment and Decision Making (PJDM) framework [5] and

the Coach Competence Model [6] highlight that coaching expertise cannot be reduced to technical proficiency alone; rather, it is the integration of knowledge, values, and behaviors in context that underpins effective practice. These perspectives challenge generic, linear coach development pathways and call for more nuanced, responsive systems that align with the realities of specific sporting environments.

Furthermore, the concept of 'coaching effectiveness' is increasingly being linked to the development of coaching capabilities, that is, adaptable, applied skills that evolve through experience and are shaped by social and organizational contexts [7,8]. Capability-based approaches to coach development emphasize reflective practice, adaptive expertise, and learning-in-action [9,10], elements that are particularly relevant in equestrian sport, where variables such as the horse's behavior, rider experience, safety concerns, and discipline-specific demands require ongoing judgment and responsiveness from the coach [1,11].

Despite these advancements in coaching science, equestrian coaching research remains relatively underdeveloped, with limited attention paid to how equestrian coaches learn, adapt, and perform in diverse contexts. Given the sport's unique demands, including the need to manage risk, build trust with both horse and rider, and navigate a spectrum of recreational to elite settings [1], there is a clear need to better understand the capabilities that underpin effective equestrian coaching [12]. Moreover, current qualification frameworks may not fully capture the contextual and practical learning that coaches acquire through real-world experience and, therefore, may be unable to fully support coaches.

By concentrating on expert coaches, those identified for their expertise and influence, this study sought to uncover not only what expert capabilities look like in equestrian coaching, but also how they are developed, supported, or constrained within

existing coach development pathways. By situating equestrian coaching within the broader discourse on context-sensitive and capability-driven development, this research aimed to contribute to a more informed, relevant, and sustainable model for coach education in equestrian sport at all levels.

2. Method

Following institutional ethical approval, expert coaches were recruited using purposive sampling. Inclusion criteria required participants to: (a) be aged 18 years or older; (b) be currently coaching within Olympic equestrian disciplines in the United Kingdom (show jumping, dressage, or eventing); (c) be actively coaching within regional or national academies and/or World Class Development Programs; and (d) hold a recognized coaching qualification, specifically a UKCC Level 3 or Level 4, BHS Instructor (BHSI), BHS Fellow, or BHS Level 5 Performance Coach qualification.

Expert coaches who met these criteria had previously been identified and selected by the British Equestrian Federation (BEF) through its National Governing Bodies: British Eventing, British Dressage, and British Showjumping. These organizations recognized the coaches as operating within the performance development sphere, with extensive experiential and professional expertise and a proven record of performance coaching.

Eligible coaches were contacted via email, provided with detailed information regarding the purpose and procedures of the study, and invited to participate. Seven expert coaches (five females and two males), all currently coaching within Olympic equestrian disciplines, consented to take part in the study. Participants were subsequently asked to provide a suitable date and location for their interview. Interviews took place at coaches' homes or stables in a quiet room. Participant demographic information is presented in **Table 1**.

Table 1: Coaches demographics.

Coach	Gender	Age	Athletic experience	Education	Years Coaching	Age of participants	Coaching context	Current certification	Years held certification
C1	F	49	National dressage/eventing	Postgraduate degree	31	>13 years	Academies	Equivalent UKCC Level 4	11
C2	F	41	National show jumping	Degree	25	All Ages	Academies	UKCC Level 3	8
C3	F	59	International dressage	High school	44	All Ages	Academies	UKCC Level 3	8
C4	M	45	International eventing, national show jumping	Postgraduate degree	30	>13 years	Academies	UKCC Level 4 (x2)	5
C5	M	46	International eventing	Degree	20	>13 years	World class development	Equivalent UKCC Level 3	12
C6	F	40	International dressage	Postgraduate degree	20	>13 years	Academies, world class	Equivalent UKCC Level 4	2
C7	F	52	International show jumping	Postgraduate degree	32	>13 years	World class development	UKCC Level 4	4

UKCC = United Kingdom Coaching Certificate

2.1. Interview Design

The interview guide (see **Supplementary Materials**) was based on Navin's research [13] on "The development of a sport-specific coaching system to support the participant Pathway." Minor adaptations were made to the interview questions to cater to the differences in equestrian sport. An introductory 'word web' was developed (see **Supplementary Materials**) and used to trigger thoughts and ideas associated with the study's key research questions. Words and phrases used on the word web were carefully selected from the literature within the subject area [9,13–15], introducing the topic without leading the interviewee toward certain answers.

The semi-structured interview used open-ended questions designed to encourage discussion and reflection on the participants' development as coaches. A semi-structured interview approach was selected to ensure comparability across participants while retaining the flexibility to probe the individuals' experiences, a methodology widely used in other sporting disciplines to generate rich, credible, and contextually grounded data [16,17]. The interviews were carried out by the same researcher (ACH) to ensure coherence and consistency between the interviews. Questions were modified within interviews to reflect emerging theory [18]. The lengths of the interviews ranged from 21 to 86 minutes (mean = 45 min).

The semi-structured interview began with questions focused on coaching contexts (for example, "Do you feel there are distinct contexts or domains within your sport, and could you define them?") and capabilities for performance development coaches (for example, "What do you need in your coaching toolbox?"). The final part of the interview consisted of questions regarding the development of expertise (for example, "When, where, and how does this coaching expertise develop?" and "How is it best learned?") and allowed participants to add any final information they felt was relevant to the study. Attention was drawn to participants' feelings, comments, and reasoning as they discussed the issues. 'Elaboration' and 'clarification' probes, as well as follow-up questions, were used to clarify participants' answers, add depth, elaborate on the context of the answers, investigate the implications of responses, and pursue the central themes revealed.

2.2. Data Analysis

All audio recordings were manually transcribed verbatim by the same person (ACH) to ensure that a complete and accurate documentation was obtained. This amassed 86 single-spaced pages of data. Following several readings, the data were then coded through the creation of analytical codes, concepts, categories, and themes developed from the data rather than existing conceptualizations [19].

Using Corbin and Strauss' work [20], data were coded by extracting concepts, which are defined as words that stand for ideas or interpretations contained in data, as products of

analysis. These concepts were then organized into categories and themes representing relevant phenomena and enabling the researcher to reduce and integrate the data [20]. Data could then be presented in an interpretable and meaningful form for peer dissemination. Data analysis concluded when theoretical saturation of concepts was attained, and no new ideas were emerging from interviews.

Coding was carried out by the primary investigator (ACH), who developed an initial code set through an iterative and inductive engagement with the data, informed by her professional background and reflective awareness of her own interpretive lens. To enhance analytic rigor and support triangulation, an experienced secondary researcher (DC) independently reviewed the coded dataset and compared interpretations. Any discrepancies were explored collaboratively, allowing for reflexive discussion and convergence of perspectives. Through this process, a consensus was reached, and a final, agreed-upon coding framework was established.

Identities of participants were only known to the primary investigator (ACH). All data were handled confidentially. All data collected were stored throughout the research process and disposed of appropriately according to the Data Protection Act of 2018.

3. Results

Participating coaches considered coaching their primary source of income. Coaches were additionally involved in coaching across all nine regions of the United Kingdom, providing a broad geographical research base. Participants' demographics, coaching context, and current coaching certifications are shown in **Table 1**.

The thematic analysis revealed two major themes (**Table 2**). First, Expert Coaches are coaches with expertise and experience. Secondly, expert coaches are adaptable, working comfortably across multiple coaching practice contexts rather than exclusively within performance development. Coaches emphasized that most coaching capabilities are required in all contexts, albeit to varying degrees. Nine categories emerged within these themes, suggesting that effective coaching extends beyond technical and tactical instruction to enabling athletes to become autonomous. Participants recognized the importance of influencing riders psychologically and emotionally, not just through skill instruction. These coaches actively seek transferable skills and value knowledge from expert coaching in other sports, viewing cross-disciplinary learning as beneficial to their development.

3.1. Coaching Expertise and Experience "Expert"

Analysis of raw data concerning competencies resulted in the grouping of coaching capabilities under four themes: attitudes, behaviors, skills, and knowledge (**Table 3**). These headings were not purposefully aligned to British Equestrian (BEF) [21] requirements but logically suited the raw data concepts and categories produced through data analysis.

Table 2: Thematic analysis of coaching expertise and contexts.

Theme	Categories	Supporting quotes
Coaching expertise and experience "Expert"	Perceptions of expertise	"For me, the word expert implies you have full knowledge of something..." (Coach 7) "To be an expert, you need experience and knowledge..." (Coach 5)
	Importance of experience and knowledge	"For me, an expert would know all about training horses and about coaching..." (Coach 3)
	Ongoing learning and continuous development	"You need to constantly be learning... CPD is huge..." (Coach 7) "I develop my own performance... so that I don't get stale..." (Coach 3)
Coaching contexts "Belonging"	Defining coaching contexts	"There is a system, isn't there?... You have your Fledglings, then you have BYRDS..." (Coach 6)
	Adaptability across contexts	"As a coach, I am happy to work with everybody, from grassroots to international..." (Coach 7) "I think you are a bit of a chameleon..." (Coach 1)
	Coaches do not work in a single context	"I feel I am quite happy across the spectrum... I feel I deliver across the spectrum..." (Coach 4)
	Limitations of the context within a pathway	"I think in some ways they interact... you can't have elite performance without adult participation..." (Coach 1)
		"I have to work in all of them, because it is the only way I can earn a living..." (Coach 3)
		"This looks to me like a pathway... it's something I can identify with..." (Coach 5) "I could have riders in here (Adult Participation) that are better than riders in here (Performance development)..." (Coach 3)
	Performance development as a broad concept	"Performance development for me is anybody that wants to keep improving their performance..." (Coach 7) "Performance development is pretty much what it is all about..." (Coach 4)
	Concerns about specialization in a single context	"I don't think anybody should be exclusive to any particular area..." (Coach 5)

3.2. Coaching Context "Belonging"

Coaches advocated that the majority of expert coaching capabilities are required across all contexts, though utilized to varying degrees. The context that coaches felt required the most distinctive set of skills was coaching riders aged 12 years and under.

"No actually, I think they would need the same things in their toolbox, they might not need the depth of knowledge so much, but they would certainly need to have an understanding of the aspects... I think the toolbox is perhaps not as full, but it's definitely got the same basics in there... you would probably wear a slightly different hat." (Coach 2).

"I wouldn't see any difference in someone's coaching skill between 13 to elite, those four boxes, in their knowledge. What I would expect is that... by the time the rider is elite, they probably don't need much more from their coach apart from... being... analysis and assessed." (Coach 6).

"The strongest skill a coach has to have is communication, and more so with the performance pathway, because very often they are working under a certain level of pressure trying to achieve performance, and normal communication skills might not work." (Coach 7).

The researcher was subsequently required to clarify whether coaches perceived any capabilities that might identify a coach as an exceptional performance development coach:

"You must be of an open mindset... You need to be very organized; you need to be very structured... anyone that knows me will tell me I am forward-thinking. I am constantly looking for another way, a better way. I have a strong ethic of reflection... And I believe with youth especially... that I am inspirational as a coach." (Coach 7).

"Be a good communicator, generous with their knowledge, and be able to mentor them, so gaining the trust of the athlete." (Coach 6).

"You've got to have a knowledge base... trust and respect... managing the politics." (Coach 4).

"For me, I am enabling people to not only ride, but also to process, so they can make a decision when they are on their own." (Coach 6).

These findings suggest that coaches are more comfortable with a definition of an 'expert performance coach' as one which includes coaches being able to work in any context and impact learners through vastly more than their technical or tactical knowledge.

Table 3: Thematic structure of expert performance coaches' expertise and experience.

Themes	Categories	Capabilities
Attitude	Coach-rider relationship	Open and honest
		Trusting
		Mutual respect
		Enabling (autonomy)
		Approachable
	Inspirational	Philosophy
		Sympathy/empathy
		Open-minded
Behavior	Passionate	Forward-thinking
		Hard working
		Mental toughness
		Discipline focused
	Developing confidence	Always learning (CPD)
		Supportive
		More interpersonal
		More interactive
Skill	Communication	Use of language
		Learning styles
		Reading personalities
	Emotional intelligence	Team management
		Controlling pressures
		Managing conflict
	Performance management	Creative and innovative
		Organized/structured
		Profiling
		Planning and goal-setting
Knowledge	Coaches' experience (tacit knowledge)	Talent identification
		Reflection
		Training horses
	Professional knowledge	Competing
		Coaching
		Depth of knowledge
		Mentoring
		Auxiliary support

3.3. Developing Expertise "Benchmarking" and "Becoming"

Perceived learning situations reported by performance development Coaches along their pathway to 'expert' status are detailed in **Table 4**.

Coaches spoke predominantly about a combination of knowledge and experience impacting their growth, commenting that "you have to do your time" and that you never stop learning.

"You don't necessarily have to be a good rider to be a great coach; I think it would be one of those things that I would put in brackets, but it helps." (Coach 2).

"I personally suspect there is an element of you either can or you can't... you've got people who have qualifications until the cows come home but can't really deliver." (Coach 4).

This suggests that successful coaching in equestrian sport is highly reliant on previous experience as a rider, trainer, and coach, as this provides an essential understanding of the sport. There is also a strong belief among coaches that the exclusive provision of technical and tactical knowledge is insufficient for coach development and that more holistic knowledge, including pedagogy and psychology, is required. Coaches also expressed concerns regarding the provision of coach education through a formal environment, particularly within equestrian sport:

"... It's also being able to develop your psychological equine and psychological human side, so you are able to also feel what is going on..." (Coach 1).

"Educational environment is crucial to the development of any coach... it (formal education) closes people's thought processes down, becomes negative, certainly in our sport, the people are outdoor, hands-on sort of people who can't really sit behind a desk... it just creates an environment where people don't want to learn." (Coach 7).

4. Discussion

This study aimed to explore the capabilities and practices of expert equestrian coaches, focusing on how these are developed, supported, or constrained within existing coach development pathways. By examining the unique relationship between coach and rider, the research seeks to provide insights that can inform context-sensitive, evidence-based approaches to equestrian coach education.

4.1. The "Expert": Expertise and Experience

This study found that extensive knowledge and experience are vital for coaching expertise in equestrian sport. This knowledge base is all-encompassing, with coaches suggesting that requirements far beyond technical and tactical knowledge are essential. Conceptual knowledge, both declarative and procedural, was considered a primary characteristic of effective coaches in analogous research [14,15,22–25]. Effective coaches can translate their experiences into knowledge through a process of reflection, allowing expert coaches to 'see things' that others may not [26].

Table 4: Learning situations reported by expert performance development equestrian coaches.

Learning situation	Description
Coach education programs	UK coaching certificate UKCC assessor British showjumping excels coaching program Elite coach apprenticeship program
Clinics/seminars	Expert/professional coach
Personal experiences related to:	Riding experience Coaching experience Being coached
Face-to-face interactions with other coaches	On UKCC courses In seminars Communities of practice
The Internet	Web Coaching subscriptions
Books/videos	Technical/tactical information
Formal mentoring	Mentoring and being mentored
Reflection	Self-reflection on all the above

Coaches emphasized a broad experience base, which included extensive coaching experience, a successful competitive riding background, and experience in training horses to a similar level to what they coach. All coaches in this study had competed at either national or international level in their respective equestrian discipline and reported that athletes' respect was initially based on coaches' competitive success and perceived knowledge [1,27]. This requirement for a broad experience base correlates with the unique nature of equestrian sport, where a strong partnership between human and animal and the development of 'feel' are essential for success [1,28].

While some coaches identified as experts, others perceived expertise as unattainable 'full knowledge' and emphasized the importance of lifelong learning [29]. It has been suggested that future research may differentiate expert coaches from less successful coaches by examining athletic backgrounds and time invested in coach learning and development [30]. Within equestrian sport, exceptional coaches exemplify a combination of absolute and relative expertise [1]. They are 'exceptional people' within their domain, who have distinct journeys from novice to master.

4.2. Coaching Contexts

Findings suggest that equestrian sport, and subsequently coaching contexts, are distinctive from most other sports [9,13,31,32]. Coaches acknowledged the value of equestrian coaching pathways for both coach and athlete but stated that their contexts have changed over time and that this contributed to their development into their current coaching positions. While coaches aimed to progress along the 'pathway', with ambitions to work with elite performers, they identified an overlap between contexts and suggested that the current framework is over-simplified given the dynamic nature of equestrian sport, where progression not only depends on the rider (with Olympic riders ranging from 16 to

71 years old) but also on the horse [31]. Coaches recommended a reconceptualization of coaching context pathways to allow flexibility and/or adjustments to age-group contexts, if included, to better align with competition structures.

It has been cautioned that coaching contexts may overlap [30], and this was evident in the findings. Coaches willingly and effectively worked across a range of contexts, likely due to the currently limited pool of equestrian performance athletes and the individualistic and elite self-coaching culture of the sport [1]. Coaches also acknowledged that although several of their 'performance development' athletes would similarly slot into the 13–18-year-old transition phase, they were not exclusively drawn from these contexts. Considering this, caution is recommended when applying the concept of coaching contexts and capabilities to equestrian coach education. It is also suggested that the athlete pathway be taken into consideration, ensuring fluency in transition between stages, as coaches acknowledged a need for congruency in information provided to athletes at every stage. Finally, coaches identified controversy with the term 'performance development,' suggesting that it represents the primary role of a coach rather than a context. It is therefore suggested that the term 'performance development' be reconsidered, potentially adopting 'talent development,' as used in hockey coaching research [9].

4.3. Coaching Capabilities

Expert equestrian coaches have a diverse set of personal characteristics, as well as distinct backgrounds as athletes. Differing from [9] and [13] in hockey and netball, coaches felt that the majority of 'expert' coaching capabilities are required within all contexts, but they are utilized to varying degrees. The most distinct context was riders aged 12 years and younger, where coaches needed to be more innovative and creative while teaching the fundamentals of riding, and coaches were least likely to have athletes within this context. Although the coaches identified capabilities required within the high-performance context, the apparent overlap between contexts suggests that 'expert' coaching capabilities are perhaps more about whom people ARE, than what they do [33]. Following this, a distinction is therefore recommended between coaching capabilities and competencies.

Essential attributes of all coaches in this study were identified as open-mindedness, passion, and a hunger for knowledge. The study reinforced the importance of coaches' investment in the coach–athlete relationship, including trust, mutual respect, open and honest communication, empathy, confidence-giving, and creativity [9,13,34]. While team sports coaches may exert more ownership and responsibility within the coach–athlete relationship [9], equestrian sports frequently operate individually, often without external assistance during competition [1], explaining the emphasis coaches placed on enabling their athletes to be completely autonomous [34].

Coaches emphasized being open-minded, forward-thinking, and lifelong learners. Coaches warned that within equestrian sport, failing to remain open-minded would limit a coach's progression and capabilities. Coaches in this study conveyed intense passion for coaching and expressed the need to be hard working and mentally tough,

as a coach's role is multifaceted and generally not monetarily rewarding [35]. It has been suggested that coaches also require structure, the ability to profile athletes, and the capacity to support flexible and adaptable goal setting on performance pathways [9,14,36]. Performance development coaches felt they influenced their participants more through 'craft' knowledge (pedagogy, emotional intelligence, and social skills) than through technical or tactical knowledge. Although coaches did not explicitly refer to emotional intelligence, they spoke of managing teams, pressures, conflicts, and reading personalities. These capabilities align with the definition of emotional intelligence as 'managing the interplay between human cognition and emotion' [36]. Emotional intelligence and management in equestrian sport may be more pertinent than other sports, due to the effect that a rider's emotional state can have on the horse [37–40], and should therefore be considered a core capability for equestrian coaches across all domains.

Finally, coaches spoke at length about auxiliary support within the performance development context. This auxiliary support includes knowledge of individuals who can provide additional services [13,41]. However, unlike many other sports, auxiliary support in equestrian sport also encompasses the multiple supporting roles a coach may be required to adopt (counselor, advisor, psychologist, nutritionist, etc.). This appears to be distinctive to equestrian sport, where the rider makes many of the performance planning and management decisions [1].

4.4. Coach Development

This study also explored how expert coaches learn and develop excellent coaching practice, informing coach education for emerging equestrian coaches. The learning and development process through which the coaches journeyed can be understood through Jarvis' theory of human learning [42]. Coaches spoke extensively about their personal journey or "biography," indicating that learning is socially constructed and experience-driven [43]. The experiences were additionally contextualized and defined as either mediated or unmediated. Through reflection, coaches translated these experiences, cognitively, emotively, and practically, into contextualized knowledge and skills [22,44–47], and developed a personal philosophy surrounding these experiences, which subsequently influenced their attitudes and behaviors.

While this study advocates a more holistic approach to coach education [4,7,48], placing more value on informal education [30], coaches also recognized a place and purpose for formal learning within equestrian sport. Furthermore, as coaching was recognized as a practical endeavor [23,26], and no coach in this study had entered coach education as a "blank slate" due to extensive experience in equestrian riding, training, and coaching [49], it was cautioned that coach education, regardless of context, if over-simplified, irrelevant, and inappropriate in delivery, risks "shutting down minds" and restricting the development of potential expert or beacon coaches [50].

Imaginative, dynamic, and thoughtful coaches require education aligned with these needs [51]. Equestrian coaches are social and practical beings, operating in social environments, and knowledge is socially established and mediated.

This research subsequently suggests that coach education, while valuable, is not a substitute for experience. Therefore, experience should be incorporated into coach certification, with mentoring and reflective practice supporting the translation of knowledge into effective coaching [43,45,52].

4.5. Limitations

Although aspects of equestrian coaching have been examined previously, the literature remains limited regarding coaching context, discipline, and rider performance level. Consequently, this study was confined to expert coaching within Olympic equestrian disciplines and performance development environments, and the findings were therefore context-specific and not intended to be generalized beyond these settings. Furthermore, while equestrian sport is often conceptualized as comprising distinct coaching contexts, the results of this study suggest that there may be greater overlap between these contexts than initially assumed. This potential overlap represents a limitation in interpreting contextual boundaries and may reflect the unique, multidimensional nature of equestrian coaching. A further limitation was that participant validation of the final themes was not undertaken, which may have reduced the credibility and confirmability of the qualitative findings.

It should be acknowledged that the recruitment of coaches may have introduced bias, as these coaches were preselected by the BEF and National governing bodies based on their certification and experience, and their perspectives might not reflect those of all equestrian coaches in this context.

Finally, a single-method approach of semi-structured interviews, while a valid form of qualitative research, only provided participants' perceptions of the roles of the coach. The inclusion of coaching observations from video analysis could provide further insight into the coaching roles displayed in practice.

5. Conclusion

This study positioned the expert coach in equestrian sport as an individual distinguished by extensive equestrian knowledge, supported by substantial experiential foundations, such as competitive riding backgrounds and long-term, varied coaching involvement. Coaches demonstrated the need to work across multiple contexts, often for financial sustainability, revealing considerable overlap in the capabilities required across settings. These findings indicate that the current British Equestrian Federation coaching pathway may oversimplify the complexity of real-world coaching practice, highlighting the need for a more nuanced approach to contextual differentiation in coach education. Coaches also challenged the term 'performance development,' arguing that developing athletes is central across all contexts, and suggesting that 'talent development' may be a more accurate descriptor.

Coaches identified a range of core behaviors such as open-mindedness, passion, trust, respect, honesty, and confidence-giving, alongside key skill themes such as performance management, communication, reflection, and emotional intelligence. Knowledge requirements centered on both professional expertise and lived experience, aligning with previous research. Participants emphasized their

role in fostering athlete autonomy and expressed a strong commitment to lifelong learning, noting that formal education cannot replace experiential understanding. This study provides a foundation for further exploration of coaching across additional equestrian contexts, and future research should employ consistent methodologies to allow meaningful comparison. Importantly, emerging work must continue to prioritize coach development that safeguards the well-being of both riders and horses, reflecting contemporary ethical expectations within equestrianism.

Supplementary Materials

The **Supplementary Materials** include the semi-structured interview guide used in this study. Additionally, a "word web" tool is provided, which was employed during interviews.

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Authors' Contributions

A.C.H.: Conceptualization, Methodology, Data curation, Formal analysis, Writing – original draft, Writing – review & editing, Project administration; V.L.: Formal analysis, Writing – original draft, Writing – review & editing; L.D.: Writing – review & editing; L.C.: Writing – review & editing.

Data Availability

The data supporting the findings of this study are available upon request from the corresponding author.

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Conflicts of Interest

The authors declare that there are no conflicts of interest.

Ethical Approval

This study received ethical approval from the Hartpury University Ethics Committee. The study complied with the guidelines of the Declaration of Helsinki.

Declaration of Generative AI and AI-Assisted Technologies

During the preparation of this work, the authors used Microsoft Copilot, in order to improve readability. Following the use of this tool, the authors reviewed and edited the content as needed and take full responsibility for the final version of the publication.

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A Preliminary Investigation into Forage Dunking Behavior in Horses in the UK

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Abstract

Forage dunking refers to a horse collecting forage with its mouth, dunking it in a nearby water source, and eating the dampened forage as it normally would. It is primarily thought to function as a method to rehydrate the forage or is observed when dental pathology is present, though limited research has been undertaken into this specific behavior. This study aimed to determine the prevalence of forage dunking behavior in horses in the UK and potential relationships between the behavior, horse activity, or management practices. An online survey consisting of 20 closed-answer questions was distributed via social media for 3 weeks. Questions focused on horse demographics and their daily management practices, and the presence of forage dunking behavior. Likert scale statements were aimed at gaining further insight into potential influencing factors. A chi-square test of association was used to analyze the collected data. Based on 414 valid responses, a prevalence of 42.7% ($n = 161$) was reported for forage dunking. This was significantly ($P < 0.05$) higher in dressage horses (54.8%) compared to other disciplines (36.4–51.0%). Horses housed in American barns were also more likely ($P \leq 0.001$) to dunk their forage compared to horses housed in other stable designs. While 50.3% of owners reported that feeding dry forage increased forage dunking behavior compared with feeding soaked or steamed forage, soaking or steaming did not eliminate the behavior ($P > 0.05$). Of the 71 horses with reported health conditions, 46.5% ($n = 33$) were reported to dunk their forage, especially those with laryngeal hemiplegia (83.3%). Results from this study suggest that forage dunking may not only be used to rehydrate forage but may, in some way, be used to make the forage more acceptable or palatable to horses with respiratory disorders, particularly those with laryngeal hemiplegia. Forage dunking behavior was not eliminated by feeding soaked or steamed forage; thus, the reasons behind this activity need further investigation to determine if this behavior is beneficial or detrimental to equine health.

Keywords

Equine; forage dunking; prevalence; stabling; respiratory conditions

1. Introduction

Domesticated horses are fed conserved forages, hay, and haylage, as part of their diet to meet their nutrient, behavioral, and digestive health requirements, especially when grazing is limited [1]. Within the UK, the most popular forage fed is hay, which can be either from a mixed grass species sward and termed meadow hay or consist of single

ryegrass or timothy grass [2], referred to as seed hay. All hay is conserved by air drying in the field and must reach >85% dry matter (DM) to ensure good preservation. Good quality hay plus a balancer can supply a high proportion of the nutritional requirements for most leisure horses and, as such, is a highly valuable constituent of the daily ration. However, hay has been identified as one of the main sources of airborne respirable dust particles (ARDP) in the stable

environment, which can result in respiratory conditions such as equine asthma [3,4].

To combat this dust, horse owners may soak the hay to remove ARDP. Soaking the hay for 10–30 minutes has been shown to significantly ($P < 0.01$) reduce ARDP levels by up to 96% [5,6]. High-temperature steaming has also been shown to be highly effective at reducing ARDP while also conserving the nutritional profile of the forage, unlike soaking, which can leach out valuable nutrients [7]. Hay may also be soaked or steamed for longer periods (up to 16 hours) for the purpose of reducing the water-soluble carbohydrate (WSC) levels as part of equine weight loss management [8–11]. While it has been suggested that this loss of WSC as a result of soaking or steaming can result in a decreased palatability of the hay [12,13], no significant differences have been reported within preference tests [14,15].

Horses have also been reported to dunk their forage in their water buckets, typically referred to as "forage dunking" or "forage wetting" [16–20]. This behavior consists of the horse collecting forage with its mouth, proceeding to dunk it in its water source and then ingesting it as normal. While mention of forage dunking has been made in research papers, limited research has been undertaken to understand the prevalence or potential role of this behavior. It has been suggested [17] that this is a normal behavior that horses may use as an attempt to rehydrate and soften their forage, especially hay due to its higher DM content, making the forage easier to chew. As such, it is also feasible that this behavior may be used by stabled horses to reduce ARDP levels in their breathing zone [21] or could be associated with dental pathologies in horses due to the softer texture.

As no specific research has been undertaken into the prevalence of forage dunking as a behavior or its potential link with horse health, the aim of this study was to investigate the occurrence of forage dunking behavior in horses in the UK and to determine if any relationship existed between dunking behavior, horse health, or management practices.

2. Materials and Methods

A cross-sectional study design was selected to answer the study aims, using an online survey aimed at horse owners in the UK. Ethical approval was gained from the Hartpury University Ethics Committee (ETHICS2014-171-LR) before the start of the study.

2.1. Survey Design

An online, anonymous survey was created using Microsoft Forms (see **Supplementary Materials**). Prior to data collection, a pilot study was conducted to ensure the clarity and validity of the questions included within the survey. For the pilot study, the questionnaire was distributed to 10 horse owners with various backgrounds, and revisions were made prior to final administration.

The survey consisted of 20 closed-answer questions, including multiple-choice and Likert scale questions. The first part of the survey focused on collecting information on the respondent's horse, including age, breed, and discipline. Further questions focused on daily management practices, gaining information around the inclusion of forage in the

diet, weight management, respiratory health conditions, and stabling and turnout management. The second part of the survey focused on forage dunking behavior. Respondents were asked to identify whether their horse had shown forage dunking behavior. A definition of forage dunking was provided within the survey to ensure all respondents had an understanding of the behavior that was being referred to. Using branching within the survey, respondents were directed to a series of Likert scale statements if they indicated that their horse showed the behavior or if they were unsure. A total of 9 Likert scale statements, using a 5-point (1: strongly agree to 5: strongly disagree) scale [22], focused on potentially influencing factors for forage dunking behavior. The use of a 5-point Likert scale is reported to be the most used scale in related research [22] and therefore was deemed most suitable for the purpose of this study.

2.2. Participants

The survey was aimed at horse owners and carers in the UK, aged 18 years and older. To record the prevalence of forage dunking behavior, the survey was aimed at owners of horses which did or did not display the behavior. An *a priori* sample size calculation with a confidence level of 95% and a 5% error margin determined that a minimum sample of 384 respondents was required, based on the number of horse owners registered in the UK [23].

2.3. Data Collection

The survey was distributed via social media platforms, including Facebook, Instagram, X, and LinkedIn between 11th–31st December 2024. Following an introduction to the aim of the study at the start of the survey, respondents were required to confirm that they were aged 18 years or older and that they consented to their data being used for the purpose of the study. Due to the anonymous nature of the survey, withdrawal of submitted responses was not possible. If the respondents left the survey prior to submitting their answers, no record of their responses was made.

2.4. Data Analysis

Data were entered into IBM SPSS for Social Sciences 29.0 for data analysis. Collected data consisted of nominal and ordinal variables, for which descriptive statistics, including frequencies and percentages, were determined. For prevalence estimations, forage dunking responses were recoded into binary variables (present / absent), with "unsure" responses treated as missing data. Prevalence estimates were accompanied by 95% confidence intervals.

Inferential analyses were conducted using chi-square tests of association to examine relationships between forage dunking behavior and management variables, and agreement with Likert-scale statements. For these analyses, the original three-category response format (yes / no / unsure) for forage dunking behavior was retained. Statistical significance was set at $P < 0.05$. For statistically significant associations, Cramer's V was determined as a measure of effect size.

3. Results

A total of 419 responses (with a margin of error of 5%) were received, of which 5 responses were removed. This included one response from a respondent who did not confirm consent or age and respondents including information for more

than one horse. Therefore, 414 responses were used for further analysis. Horses were of various breeds and ages. The most common breeds included Warmbloods (WB, 19.8%, $n = 82$), native pony breeds (14.7%, $n = 61$), crossbreeds (14.7%, $n = 61$), and Thoroughbreds (TB, 14.5%, $n = 60$). The majority of horses were aged between 5–19 years old (82.1%, $n = 340$) but ranged from <1 year old to 20+ years old. Horses were used for a range of disciplines, with leisure horses being most represented (37.9%, $n = 157$) (**Figure 1**).

3.1. Forage Dunking Prevalence

Of the 414 responses, 37 horse owners (8.9%) were unsure if their horse showed forage dunking behavior. Prevalence of forage dunking was calculated using the remaining 377 responses, of which 42.7% of horses ($n = 161$, CI = 37.7–47.7%) were reported to show forage dunking behavior.

No significant associations were found between forage dunking and horse breed ($\chi^2 = 15.223$, $df = 12$, $P = 0.229$) or between forage dunking and age ($\chi^2 = 7.094$, $df = 10$, $P = 0.717$). However, a significant association ($\chi^2 = 19.735$, $df = 8$, $P = 0.011$, Cramer's $V = 0.154$) did exist between the horse's discipline and forage dunking behavior (**Figure 1**). Forage dunking prevalence was highest in dressage horses (54.8%, CI = 36.3–73.4%) compared to the remaining disciplines. However, the majority of respondents with horses showing forage dunking (FD group, $n = 161$) and respondents unsure whether their horses showed this behavior (U group, $n = 37$) did not feel that exercise influenced forage dunking occurrence (47.2% ($n = 76$) and 54.1% ($n = 20$), respectively).

3.2. Association Between Forage Dunking and Management Practices

Horses were reported to be housed in a range of stable designs. The majority of horses were stabled in American barns (34.3%, $n = 142$) and open-facing stables (34.3%, $n = 142$) (**Figure 2**) and were predominantly provided with water using water buckets (72.0%, $n = 298$). A significant association ($\chi^2 = 25.787$, $df = 8$, $P = 0.001$, Cramer's $V = 0.176$) was found between forage dunking prevalence and stable design, whereby forage dunking was more prevalent in horses stabled in an American barn (53.4%, CI = 44.8–62.0%) compared to other stable designs. However, there was no significant association ($\chi^2 = 19.928$, $df = 16$, $P = 0.224$) between discipline and stable design. Bedding type was not found to be associated with forage dunking prevalence ($\chi^2 = 11.202$, $df = 10$, $P = 0.342$). The majority of FD group respondents (50.3%, $n = 81$) found their horse's stable to be wet, which they attributed to this behavior, compared to 24.3% ($n = 9$) of U group respondents.

The majority of horses (93.7%, $n = 388$) received hay and/or haylage as part of their diet, which was presented primarily on the floor (47.4%, $n = 184$) and/or in a hay net (62.1%, $n = 241$). 24.7% of horses ($n = 96$) received soaked forage and 5.4% ($n = 21$) of horses received steamed forage. The majority of forage was soaked or steamed for up to 2 hours (66.7%, $n = 78$). No significant association ($\chi^2 = 10.110$, $df = 8$, $P = 0.257$) existed between feeding soaked forage and the discipline of the horses. However, a significant association ($\chi^2 = 12.771$, $df = 4$, $P = 0.012$, Cramer's $V = 0.124$) did exist between the feeding of soaked or steamed forage and the prevalence of forage

dunking (**Figure 3**). While the majority of owners (FD group: 50.3%, $n = 81$; U group: 59.5%, $n = 22$) indicated agreement with the statement that feeding dry forage increased forage dunking in their horses, feeding soaked or steamed forage did not eliminate forage dunking behavior (**Figure 3**). In addition, 64% ($n = 104$) of FD group respondents and 43.2% ($n = 16$) of U group respondents disagreed that feeding soaked or steamed forage resulted in cleaner water containers. However, only 22.4% ($n = 36$) of FD group respondents and 21.6% ($n = 8$) of U group respondents believed their horse preferred soaked or steamed forage.

Turnout time ranged from up to 2 hours per day (9.2%, $n = 38$) to up to 24 hours per day (16.4%, $n = 68$), with the majority of horses receiving a minimum of 5 hours of turnout per day (79.2%, $n = 328$). A significant association ($\chi^2 = 17.562$, $df = 6$, $P = 0.007$, Cramer's $V = 0.146$) was found between forage dunking prevalence and turnout duration, whereby forage dunking prevalence was lowest in horses turned out for 24 hours per day (21.9%, CI = 11.5–32.2%) compared to shorter turnout durations.

3.3. Association Between Forage Dunking and Respiratory Conditions in Horses

A range of respiratory or airway health conditions were reported by respondents. In total, 71 horses were reported to have been diagnosed with laryngeal hemiplegia (8.5%, $n = 6$), equine asthma (73.2%, $n = 52$), and/or choke (31.0%, $n = 22$). Out of these, 33 horses (46.5%) were reported to show forage dunking behavior, whereas 5 owners (7.0%) were unsure if their horse showed this behavior. While 12 owners (16.9%) soaked their horse's forage and 4 owners (10.5%) steamed their horse's forage, 65.8% ($n = 25$) disagreed that soaking or steaming forage reduced the occurrence of forage dunking behavior.

A significant association ($\chi^2 = 6.676$, $df = 2$, $P = 0.036$, Cramer's $V = 0.127$) was determined between forage dunking and laryngeal hemiplegia, with 5 out of 6 horses with laryngeal hemiplegia also being reported to show forage dunking behavior. No significant ($P > 0.05$) associations were identified between forage dunking and other respiratory conditions.

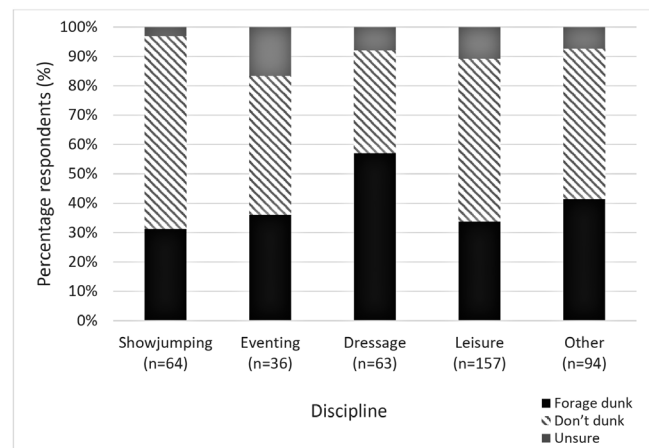


Figure 1: Distribution of horses showing forage dunking behavior across different disciplines ($N = 414$). Other disciplines included endurance ($n = 4$), racing ($n = 1$), carriage driving ($n = 3$), hunting ($n = 13$), and unspecified ($n = 73$).



Figure 2: Examples of (A) American barn stabling and (B) U-shaped stable block (photos: author's own).

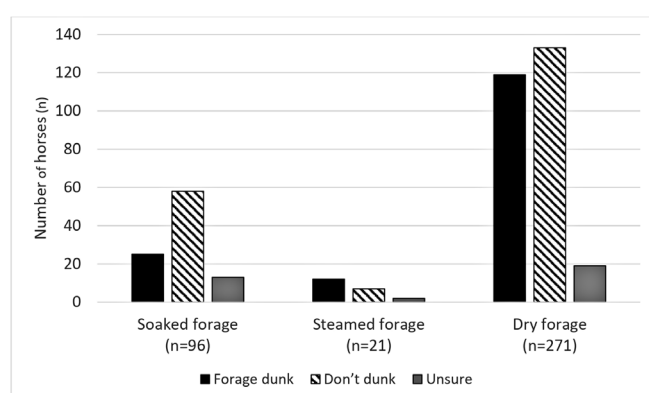


Figure 3: Significant ($\chi^2 = 12.771$, $P = 0.012$) association between forage dunking occurrence and soaked forage, steamed forage, and dry forage ($N = 414$).

4. Discussion

The identified prevalence of forage dunking behavior at 42.7% (CI: 37.7–47.4%) supports suggestions from early work that forage dunking should be considered as a normal behavior as it may serve a purpose for the horse [20]. The occurrence of this behavior in horses receiving hay may be interpreted as an attempt by the horse to rehydrate its hay [17], as hay typically has a higher DM content compared to natural forage due to the conservation process. As feed intake and feed selection in horses are influenced by somato-sensory stimuli such as taste and textures [13,24,25], forage dunking could result in a softer and more flexible structure, preferred by horses [26,27]. Indeed, in the current study, 50.3% of owners of a horse showing forage dunking behavior agreed that the frequency increased if dry forage was provided.

However, this study also found that horses receiving haylage, as well as steamed or soaked forage, still dunked their forage in their water. Both soaking and steaming of forage have been reported to increase the forage's moisture content, resulting in a softer texture [15,28,29]. Therefore, it would have been expected that soaking or steaming forage would reduce the occurrence of this behavior. It was therefore particularly of interest to note that while only 26.0% of horses receiving soaked forage dunked their forage, 57.1% of horses receiving steamed forage still dunked their forage. One aspect that was not considered within this study was whether the horses were already showing forage dunking

behavior before starting to receive soaked or steamed forage. Considering the potential purpose of this behavior, it may be hypothesized that this is a learned behavior to express their foraging and feed selection preferences [30], resulting in the horse continuing to express this behavior when forage with higher moisture content is provided.

In addition, the stable environment was identified as a potential factor influencing the occurrence of forage dunking behavior. Although a significant association ($P = 0.001$) was found between forage dunking and stable design, with 50% of horses stabled in American barns being reported to show this behavior, the effect size was small (Cramer's $V = 0.176$), indicating that additional factors are likely to contribute to this association. American barn stables have been associated with increased prevalence of inflammatory airway diseases due to the presence of ARDP as a result of the choice of bedding and forage [3,21,31]. As horses are obligate nasal breathers, being housed in environments with high ARDP levels can increase the horse's exposure to inflammatory airway diseases. While increasing ventilation can reduce the presence of ARDP, it has also been shown that soaking forage for 10–30 minutes can reduce the number of ARDP by up to 90% [7,10]. The number of horses in this study with reported respiratory conditions was comparable with the average prevalence in the UK (17.1%, $n = 71$), with 46.5% ($n = 33$) being reported to dunk their forage. As such, not only may dunking forage be an attempt by the horse to rehydrate its forage, but potentially also an attempt to reduce the dust in the forage. However, further research would be required to establish this.

It was of interest to note the significant ($P = 0.011$) association between forage dunking and discipline, with dressage horses more likely to show forage dunking behavior. However, stabling and use of soaked forage were not different ($P > 0.05$) for this discipline compared to other disciplines in this study, nor was breed found to be an influencing factor for forage dunking prevalence ($P > 0.05$). As this was an exploratory study, this should be considered carefully, as other factors could be underlying this association, as indicated by the small effect size.

While this study provides an initial investigation into forage dunking behavior, there are some limitations to the study that should be considered. Firstly, the survey relied

on owner self-reporting rather than direct observations of the behavior. Although a definition of the behavior was provided within the survey, variability in respondents' interpretation of the behavior may have influenced the reported prevalence. In addition, there was potential for owner recall bias to influence the results as well, suggesting further observational studies would be required. Secondly, although statistically significant associations were identified, the low Cramer's V values indicate small effect sizes. As such, these findings should be interpreted with caution, as additional variables are likely to influence the observed associations. Therefore, further research into the identified associations would be warranted.

5. Conclusion

This study has provided an initial insight into the behavior of forage dunking and potential influencing factors. To the authors' knowledge, this is the first study to report the prevalence of forage dunking in horses. The results from this study suggest that this behavior may be associated with management factors such as stabling and feeding of forages. This could indicate that this behavior may perform an, as yet undefined, function for some horses, such as increasing the hydration of the forage. However, as some horses still show this behavior while receiving soaked or steamed forage, this may suggest that forage dunking could be a learned behavior which is continued after management practices are amended. Therefore, further research into factors such as the influence that forage dunking has on water intake, ARDP levels in the stable environment, and palatability of forages is warranted.

Supplementary Materials

The **Supplementary Materials** include the full online survey used in this study.

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Authors' Contribution

H.B.: Conceptualization, Methodology, Validation, Formal analysis, Resources, Visualization, Writing – original draft, Writing – review & editing, Supervision. K.L.: Conceptualization, Methodology, Validation, Writing – original draft, Writing – review & editing. All authors have read and agreed to the published version of the manuscript.

Data Availability

The data supporting the findings of this study are available upon request from the corresponding author.

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No funding was received for this research project.

Conflicts of Interest

The authors declare that there are no conflicts of interest

Ethical Approval

This study received ethical approval from Hartpury University Ethics Committee (ETHICS2014-171-LR). The study complied with the guidelines of the Declaration of Helsinki.

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Tracking Horse and Rider Speed During Warm-Up and CCI4* Short and Long Format Cross-Country Using a Commercial Wearable GPS Sensor

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Abstract

There is some evidence that appropriate warm-up and pacing are key to successful performance and injury risk reduction in equestrian endurance and horseracing. To date, only limited studies of warm-up for eventing cross-country have been reported, and to our knowledge, there has been no report of continuous cross-country speed and pacing strategy. The aim of the present study was to investigate how riders warm up and the pacing strategy they use on cross-country. Riders competing in CCI4* short ($n = 11$) and long ($n = 7$) competition were fitted with a Catapult Vector S7 sensor. Ten horses completed the CCI4*S, and all 7 completed the CCI4*L. Riders spent significantly longer warming up for the CCI4*L (30.2 ± 9.2 min; mean $\pm$ SD) than for the CCI4*S (20.7 ± 7.0 min; $P = 0.029$). Mean speed on the CCI4*S was 525 ± 15 m/min (range 500–544 m/min) and was slower than the CCI4*L 557 ± 21 m/min (range 533–584 m/min) ($P = 0.002$). Variance in speed over the whole course for each individual horse (SD/mean*100) was $22 \pm 3\%$ for CCI4*S and $24 \pm 3\%$ for CCI4*L ($P > 0.05$). Mean jump speed was 404 ± 12 m/min (range 393–424 m/min) for CCI4*S and 393 ± 16 m/min (range 361–405 m/min) for CCI4*L and was not significantly different ($P > 0.05$). Differences were found in mean peak inter-fence/combination speed, 639 ± 20 m/min (range 615–674 m/min) for CCI4*S and 678 ± 28 m/min (range 634–703 m/min) for CCI4*L ($P = 0.004$). High variance in speed over the course and very low or very high fence approach speeds may potentially play a role in fatigue and/or fall risk and warrant further study.

Keywords

Equestrian; competition; jumping; safety; performance; eventing

1. Introduction

Warm-up and effective pacing strategies are recognized as critical components for optimizing human sports performance and reducing injury risk. A well-structured warm-up increases muscle temperature, enhances blood flow, and improves neuromuscular coordination, which collectively prepare the body for the physical demands of exercise. A

meta-analysis by [1] demonstrated that warm-ups incorporating dynamic stretching and sport-specific movements can significantly enhance performance metrics such as power output and agility, while lowering the incidence of musculoskeletal injuries. Additionally, pacing strategies tailored to an athlete's physiological capacity and the event's duration help maintain energy efficiency and prevent over-exertion, a key factor in injury risk reduction [2]. Effective

pacing minimizes fatigue-induced biomechanical errors, which are linked to strains and sprains [2]. Together, these practices form a foundational approach to maximizing human athletic output and safeguarding long-term health in sports contexts.

Warm-up is also a critical component of equestrian competition. A warm-up period of approximately 10–15 minutes increases muscle temperature by approximately 1–2 °C, enhancing muscle elasticity and reducing the risk of strains or tears. This temperature elevation accelerates enzymatic reactions and improves oxygen delivery via increased blood flow [3]. A variety of authors have studied warm-up in dressage, showjumping, and Thoroughbred and Standardbred racing (see review by [4]), although there are limited studies investigating warm-up for cross-country [5]. With regard to pacing, this has been studied in racehorses [6–8] and in equine endurance [9–11]. In addition, high fence approach speed has been identified as a risk factor for falls in eventing [12]. While a large number of commercial, accurate systems for speed and positioning have been available for some time, such as those produced by Garmin, Apple, and Polar, as far as we are aware, warm-up and eventing cross-country speed patterns have not been reported using such devices.

Burger *et al.* [13] reported on 54 cross-country rounds across 33 horses and five competitions, including CCI4*S and CCI4*L, using a commercial sternally mounted GPS and inertial measurement sensor (Alogo Move Pro Equine Sensor, Alogo Analysis SA, Switzerland). While this sensor has been validated for stride kinematics on the flat and over jumps, the accuracy for speed over longer distances has not been reported [14].

The Catapult Vector S7 is an advanced wearable sensor system designed for elite sports performance monitoring, offering precise tracking of speed, position, and biomechanical metrics. Integrating 10 Hz multi-GNSS (GPS, GLONASS, Galileo) and ClearSky Local Positioning System (LPS) technology, it delivers high-accuracy data in both outdoor and indoor environments, with positional precision below 1 meter indoors and speed measurement errors as low as 0.12–0.21 m·s⁻¹ outdoors, validated against laser and motion capture systems [15].

The present study aimed to investigate the use of commercially available sensors to track horse and rider speed and distance during the cross-country phase of CCI4* short (S) and long (L) format competitions using the Catapult Vector S7 sensor. The CCI4*-S (Concours Complet International 4 Star – Short) is an international equestrian eventing competition under FEI rules (Fédération Équestre Internationale) rated at the four-star level. It spans two to three days, including dressage, a shortened cross-country course (5,700–6,840 meters, up to 40 jumps, 10–12 minutes at 570 m/min), and show jumping (450–550 meters, up to 15 efforts, 375 m/min). Horses must be at least 7 years old, and riders must be at least 18 years old. The CCI4*-L (Concours Complet International 4 Star – Long) is an international equestrian eventing competition at the four-star level, using a long

format under FEI rules. Held over three to four days, it includes dressage, a longer cross-country course (6,270–7,410 meters, up to 45 jumps, 11–13 minutes at 570 m/min), and show jumping (500–600 meters, up to 15 efforts, 375 m/min). The cross-country phase is the longest and most physically demanding, with frequent acceleration and deceleration, turns, jumps, and often variable terrain and ground conditions. Appropriate warm-up and appropriate speed and pacing strategy are likely to be crucial in eventing, particularly at higher levels, to reduce the risk of early fatigue and falls and to maximize performance. The present study aimed to investigate how riders warm up for CCI4* competition and the pacing strategy they use on cross-country. Specifically, we monitored horse and rider combinations competing at the Bramham International Horse Trials (2023) from the start of warm-up until the end of the cross-country to allow us to investigate the pattern and intensity of both warm-up and competition.

2. Materials and Methods

2.1. Horses and Riders

Data were collected from 10 International-level riders competing in either or both the cross-country phases of the Bramham International Horse Trials CCI4*S or the CCI4*L in June 2023. Riders were invited privately and individually to participate by British Equestrian staff, and participation was optional. One rider who was invited declined to participate. A total of 18 cross-country rounds were recorded. Seven riders attempted 11 cross-country rounds on 11 horses (4 riders, 1 round; 2 riders, 2 rounds; and 1 rider, 3 rounds). Seven riders completed 7 cross-country rounds on 7 horses. Details of the horses are given in **Table 1**. Details of the two cross-country courses are given in **Table 2**, along with maps of the course showing the track and jump positions and elevation over distance in Figures S1 and S2 (**Supplementary Materials**).

2.2. Data Collection

Each rider was fitted with a Lycra vest and a GPS sensor (Vector S7, Catapult UK, 2a Southwark Bridge Rd, London SE1 9HA) (**Figure 1**). Catapult Vector S7 is widely used in professional sports such as rugby, football, basketball, American football, and cricket. The sensor is 81 mm × 43 mm × 16 mm and weighs 53 g. The GPS system uses standard GPS, GLONASS, and SBAS and records position ten times per second (10 Hz). Based on pilot data collection prior to this competition, it was not deemed necessary to apply any post-data collection processing to the speed data. The Lycra vest was fitted over the rider's body protector. If an air jacket was used, then this was fitted over the body protector and the Vector S7 sensor. In addition to GPS data at 10 Hz, from which speed is derived, the sensor also provides 3-axis acceleration (±16 g), which is sampled at 1 kHz and output at 100 Hz, and a 3-axis gyroscope, which provides 2000°/s output at 100 Hz.

The sensor was manually activated at the time of fitting to the rider prior to mounting, i.e., before the commencement of warming-up to record warm-up and cross-country.

Table 1: The age, sex, and breeding of the seven horses and rider ID studied in the CCI4*S and eleven horses studied in the CCI4*L competitions at Bramham in 2023.

Competition	Horse	Rider ID	Age (years)	Sex	Breed/Studbook
CCI4*L	L1	1	10	G	Irish Sport Horse (ISH)
CCI4*L	L2	2	11	G	Zangersheide/British Sport Horse
CCI4*L	L3	3	10	G	British Sport Horse (SHBGB)
CCI4*L	L4	4	10	G	Dutch Warmblood (KWPN)
CCI4*L	L5	5	12	G	Irish Sport Horse (ISH)
CCI4*L	L6	6	10	M	British Sport Horse
CCI4*L	L7	7	13	S	British Sport Horse (SHBGB)
CCI4*S	S1	2	11	M	Anglo European Studbook (AES)
CCI4*S	S2	4	9	G	Irish Sport Horse (ISH)
CCI4*S	S3	4	17	G	Irish Sport Horse (ISH)
CCI4*S	S4	5	11	G	Irish Sport Horse (ISH)
CCI4*S	S5	6	10	G	Irish Sport Horse (ISH)
CCI4*S	S6	8	11	M	Anglo European Studbook (AES)
CCI4*S	S7	8	9	G	Irish Sport Horse (ISH)
CCI4*S	S8	8	10	G	Dutch Warmblood (KWPN)
CCI4*S	S9	9	12	M	Sport Horse (British/Irish lineage)
CCI4*S	S10	9	10	M	Holsteiner (HOLST)
CCI4*S	S11	10	12	M	British Sport Horse (SHBGB)

Table 2: Cross-country course characteristics for CCI4*S and CCI4*L at Bramham International Horse Trials in 2023.

	Length (m)	Speed (m/min)	Optimum time (mm:ss)	Jumping efforts	Jumping efforts meter/effort	Total climb (m)	Total descent (m)
CCI4*S	3810	570	6:42	34	112	+88	-94
CCI4*L	5885	570	10:20	41	144	+136	-163

2.3. Data Analysis

After retrieval of the sensors from riders following completion of the cross-country, the sensor data were downloaded via the download dock to the Catapult Openfield Operator Console software. From here, data were exported as CSV files for further analysis in Microsoft Excel. The start and end of cross-country were identified from a combination of the distinctive pattern of speed (see **Figure 2**, **Figure 5**, and **Figure 6**), speed increase, and location on course from the *.kml files overlaid in Google Earth Pro.

Average speed and standard deviation of speed were used to calculate variation in speed as $SD/mean \times 100$ (% coefficient of variation; %CV). Average approach speed to each fence or fence complex (identified by both speed nadirs and position from *.kml files in Google Earth Pro) and peak and mean speed between fences/fence complexes were calculated using a Python routine run in Google Colab with visual validation. The code is available on GitHub: <https://github.com/DJ61M/Cross-Country-Speed-Peak-and-Nadir-Detection->. Shapiro-Wilk tests confirmed that the data assumed a normal distribution and met the requirements for use of parametric statistical tests. Differences between CCI4*S

and CCI4*L were investigated with independent t-tests. Significance was set at $P < 0.05$. Differences over time were investigated with ANOVA and post-hoc Tukey's test, where significance was reached. Potential relationships between jumping effort progression and inter-fence peak speed or jump minimum speed were investigated with the Pearson correlation coefficient. Data are reported as mean $\pm$ SD. Official times and records (i.e., clear, refusal, fall, hold on course, etc.) for cross-country were obtained from the organizers and from fence judge sheets. Holds on course were identified from the speed data from the sensor in conjunction with the fence judge sheets. The sections of data corresponding to the hold period were removed from the dataset for final analysis.

2.4. Ethical Approval

Specific ethical approval for this study was not required as the study involved only wearing a commercially available non-invasive sensor by athletes already competing under Team GB, posed no greater risk than routine training or wearing a watch, collected fully anonymized data with no identifiable private information, aligned with UK Sport/Team GB performance monitoring protocols, and obtained

informed consent consistent with event participation and the Declaration of Helsinki, including permission to use the data collected from them and their horses. For the time that the researchers interacted with the horses and riders, any interaction with the horses was conducted in full compliance with the UK Animal Welfare Act 2006, ensuring that all reasonable steps were taken to meet the animals' welfare needs and to prevent any unnecessary suffering, in line with the Act's provisions and the Five Freedoms framework.

3. Results

Complete datasets were successfully obtained from all horse and rider combinations. All horse and rider combinations completed the warm-up ($n = 18$). All riders completed all cross-country rounds with the exception of the rider undertaking 3 rounds on the CCI4*S, who retired one horse. This combination's data were excluded from further analysis. Therefore, data are presented for 10 combinations in the CCI4*S and 7 combinations in the CCI4*L ($n = 17$). Air temperature ranged from 20 °C to a high of 22 °C, with relative humidity ranging from 90% to 60%. The wind was around 16–19 km/h. There was no rain. Prior to the competition, there had been little rain, and there had been watering of the course. The going was considered to be good to firm.

3.1. Warm-Up

Riders spent significantly less time warming up for the CCI4*S (20.7 ± 7.0 min) than for CCI4*L (30.2 ± 9.2 min; $P = 0.029$). Peak warm-up speed was 479 ± 41 m/min for CCI4*S and 537 ± 122 m/min for CCI4*L ($P > 0.05$). The time between the last period of canter exercise during warm-up and the start of the cross-country was 6.0 ± 2.5 min (range 2.8 to 10.7 min) for CCI4*S and 3.9 ± 2.6 m/min (range 0.2–7.2 min) for CCI4*L ($P > 0.05$). The time spent standing (once warm-up had started based on walking, trotting, or cantering), walking, trotting, and cantering for CCI4*S and L is shown in **Figure 3**. There was no significant difference between competitions in warm-up duration in stand ($P = 0.720$), walk ($P =$

0.094), or canter ($P = 0.085$), but horses competing in CCI4*L spent significantly longer in trot than horses in CCI4*S (3.7 ± 1.5 min versus 1.5 ± 1.2 min; $P = 0.004$). The amount of time spent warming-up according to speed is shown in **Figure 4**, with a similar pattern for CCI4*S and CCI4*L.

3.2. Cross-Country

In the CCI4*S, 5 horses were clear inside the time, and 5 were clear inside the time but received jumping penalties. In the CCI4*L, all horses were inside the time, but 3 received jumping penalties. No horses were held on course during the CCI4*S, but 2 horses were held on course during the CCI4*L. The results for horse and rider combinations in this study are shown in **Table 3**.

An example of the speed against distance for rider 10 with fences marked is shown in **Figure 5a** for CCI4*S, with a position plot from the GPS latitude and longitude data in Google Earth in **Figure 6**. An example of the speed against distance for rider 1 with fences marked is shown in **Figure 5b** for CCI4*L.



Figure 1: Catapult Lycra vest and Vector S7 GPS unit in position over body protector.

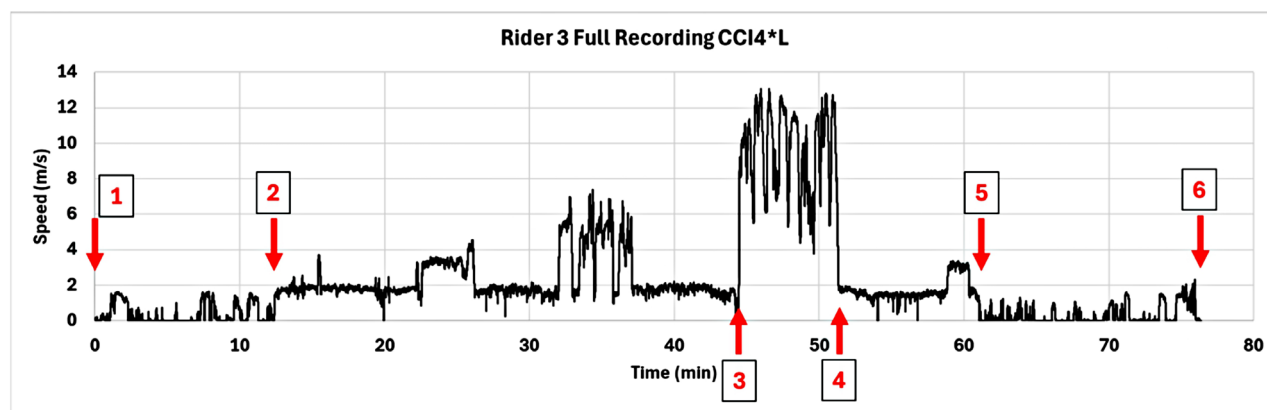


Figure 2: An example of a full recording from Rider 3 for CCI4*L. 1 – Time 0 corresponding to the Catapult sensor being turned on and the start of the recording; 2 – Rider mounts horse; 3 – Start of cross-country; 2–3 – warm-up; 4 – end of cross-country; 3–4 – cross-country; 5 – rider dismounts; 6 – sensor retrieved from rider and turned off to end recording.

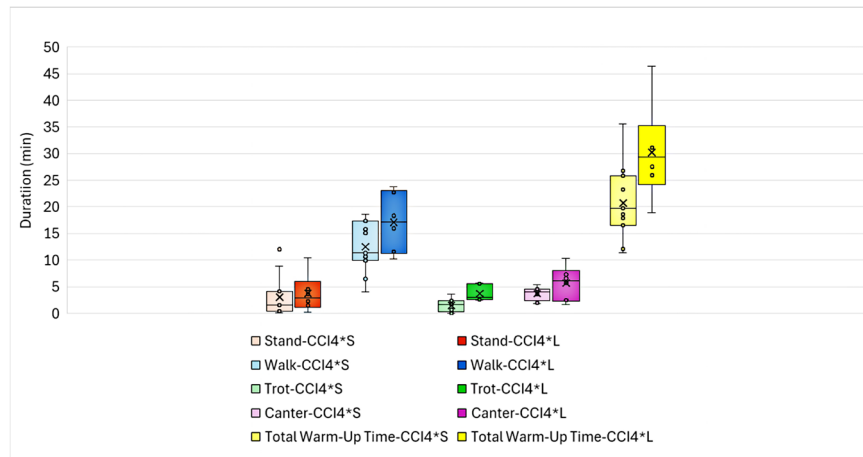


Figure 3: Duration (min) spent in stand, walk, trot, or canter and total warm-up time for horses competing in CCI4*S (n = 11) and CCI4*L (n = 7).

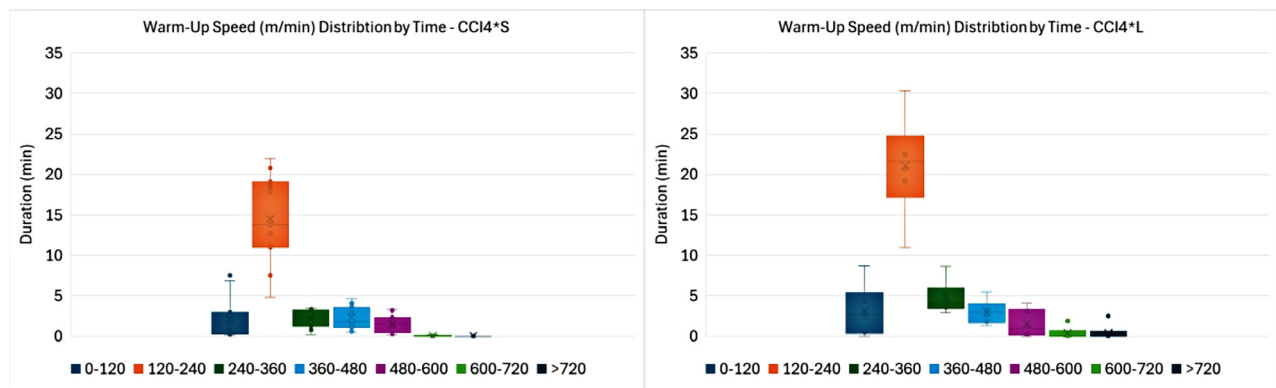


Figure 4: Duration (min) by speed brackets (m/min) for horses competing in CCI4*S (n = 11) and CCI4*L (n = 7).

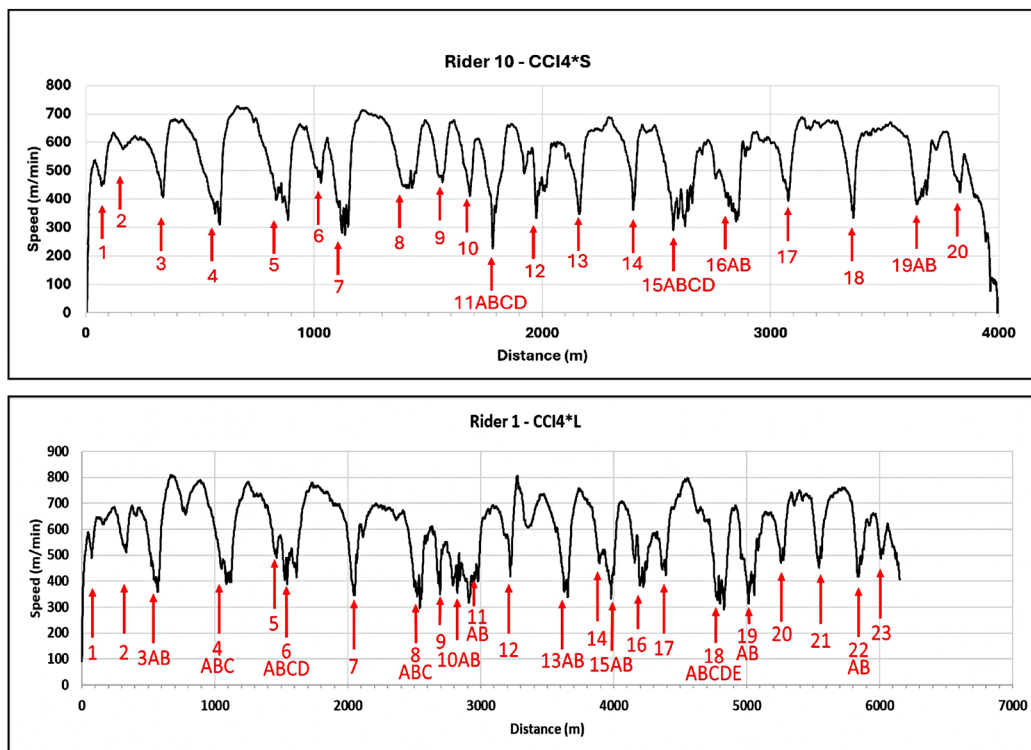


Figure 5: Examples of speed (m/min) versus distance (m) for rider 10 in the CCI4*S (a) and for Rider 1 in the CCI4*L (b). Fence numbers are marked in red.

Table 3: Full results for horses monitored in the CCI4*L (7 combinations) and CCI4*S (11 combinations) at Bramham 2023.

Competition	Horse	Rider	Dressage score	Showjumping penalties	Showjumping time faults	Cross-country jumping penalties	Cross-country time penalties	Final score	Final position
CCI4*L	L1	1	30.8	0	0	0	0	30.8	2
CCI4*L	L2	2	29.9	4	0	20	18.4	72.3	25
CCI4*L	L3	3	29.3	0	0	0	1.2	30.5	1=
CCI4*L	L4	4	29	W	W	20	16.8	W	W
CCI4*L	L5	5	32.3	W	W	11	10.8	W	W
CCI4*L	L6	6	32.2	0	0	0	2.8	35	4
CCI4*L	L7	7	26.5	4	0	0	0	30.5	1=
CCI4*S	S1	2	34.4	8	0	15	8.4	65.8	30
CCI4*S	S2	4	36.9	4	0	0	8.4	49.3	13
CCI4*S	S3	4	32.6	4	0	40	34.4	111	49
CCI4*S	S4	5	37.6	4	0	20	19.2	80.8	40
CCI4*S	S5	6	28.7	4	0	20	18.4	71.1	36
CCI4*S	S6	8	37	0	0	0	13.2	50.2	16
CCI4*S	S7	8	39.9	4	0	20	21.2	85.1	42
CCI4*S	S8	8	33	8	0	R	0	R	R
CCI4*S	S9	9	40.3	0	0.4	0	10.4	51.1	18
CCI4*S	S10	9	39.6	4	0	0	18.4	62	27
CCI4*S	S11	10	36.3	4	0	0	4.8	45.1	7

W = withdrawn; R = retired

3.3. Speed and Speed Variance

Mean speed on the CCI4*S was 525 ± 15 m/min (range 500–544 m/min) and was slower than on the CCI4*L, which was 557 ± 21 m/min (range 533–584 m/min; $P = 0.002$). Variance in speed over the whole course for each individual horse ($SD/mean \times 100$) was $22 \pm 3\%$ for CCI4*S and $24 \pm 3\%$ for CCI4*L ($P > 0.05$). Mean speed for each quarter of the course is shown in **Figure 7**. Mean speed was significantly greater for each quarter and overall for the whole course for CCI4*L compared with CCI4*S, with the exception of the final quarter of the course. Mean speed and %CV of mean speed for CCI4*S and CCI4*L as a % of the course completed are shown in **Figure 8**.

3.4. Time & Distance

The official distance of the course, the distance ridden reported by the Catapult sensor, the official completion time, and the time reported by the Catapult sensor for the CCI4*S and CCI4*L are reported in **Table 4** and **Table 5**. For the CCI4*S, the difference between the official cross-country time and the Catapult-reported time was 2 ± 1 s (range 1–3 s). This represents an error of 0.22 to 0.77%. For the CCI4*L, the difference between the official cross-country time and the Catapult-reported time was greater, 4 ± 6 s (range 1–17 s). However, it was clear that the larger discrepancy was related to the two horses held on course (+6 s and +17 s) and likely due to differences between how the hold was assessed from the recordings and by the official time from the event. Excluding these two horses, the difference was 1 ± 1 s (range –1–2 s). For the Catapult-reported distance

traveled compared with the official course distance, for the CCI4*S, this was 121 ± 105 m, representing an average increase over the official course distance of 3%. For the CCI4*L, the average distance was 218 ± 131 m longer than the official course distance, representing an average increase in distance of 3.7%. Therefore, the Catapult system demonstrated high accuracy for both time and distance, with an error always less than 0.05% for time compared with the official time and $3.4 \pm 2.5\%$ for distance. It should be remembered that the ridden distance may naturally vary from the official distance due to the specific path riders choose, and that this discrepancy does not necessarily represent a true "error."

3.5. Jump Speed, Maximum Inter-Fence/Combination Speed, and Speed Variance

Mean jump speed was 404 ± 12 m/min (range 393–424 m/min) for CCI4*S and 393 ± 16 m/min (range 361–405 m/min) for CCI4*L and was not significantly different ($P > 0.05$). Mean peak inter-fence/combination speed was 639 ± 20 (range 615–674 m/min) for CCI4*S and 678 ± 28 m/min (range 634–703 m/min) for CCI4*L ($P = 0.004$).

There was no significant correlation between jumping effort progression and inter-fence peak speed or jump minimum speed for CCI4*S (peak speed $r^2 0.02 \pm 0.02$, range 0.00–0.05, $P > 0.05$; minimum jump speed $r^2 0.03 \pm 0.06$, range –0.04–0.17, $P > 0.05$) nor for CCI4*L (peak speed $r^2 0.01 \pm 0.03$, range 0.00–0.07, $P > 0.05$; minimum jump speed $r^2 0.03 \pm 0.03$, range 0.00–0.08, $P > 0.05$).

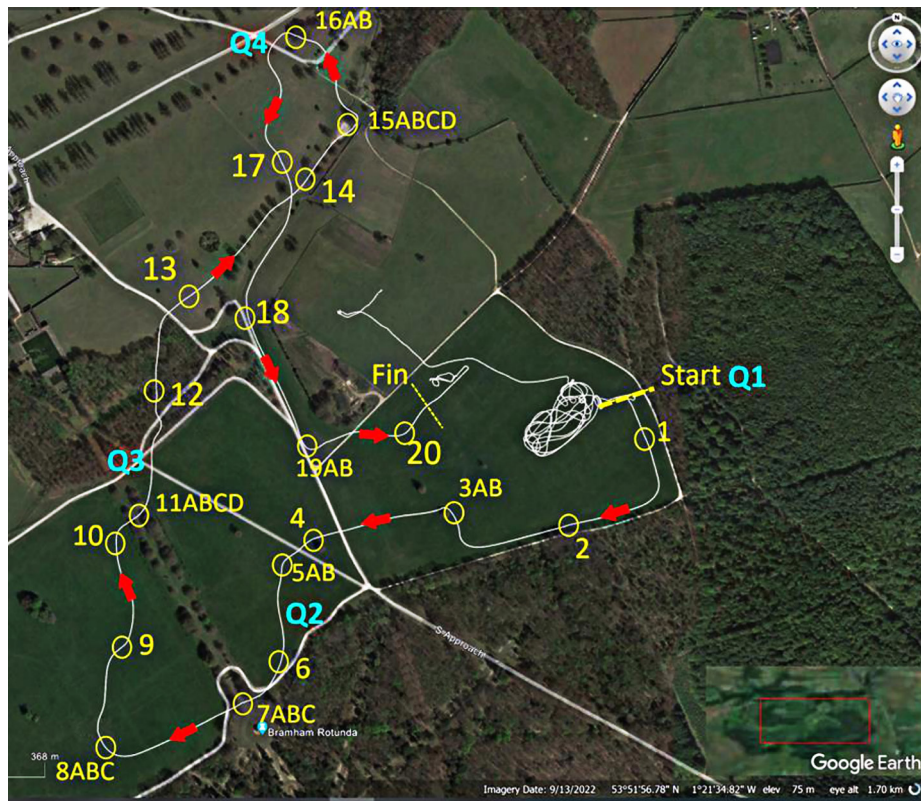


Figure 6: Actual track taken by rider 10 in CCI4*S cross-country overlain on Google Earth (white line) using the exported latitude and longitude data from Catapult. Jump locations are marked in yellow. The start of each quarter of the course is marked by blue Q1–Q4 (See **Figure 7**). Red arrows show the direction of travel.

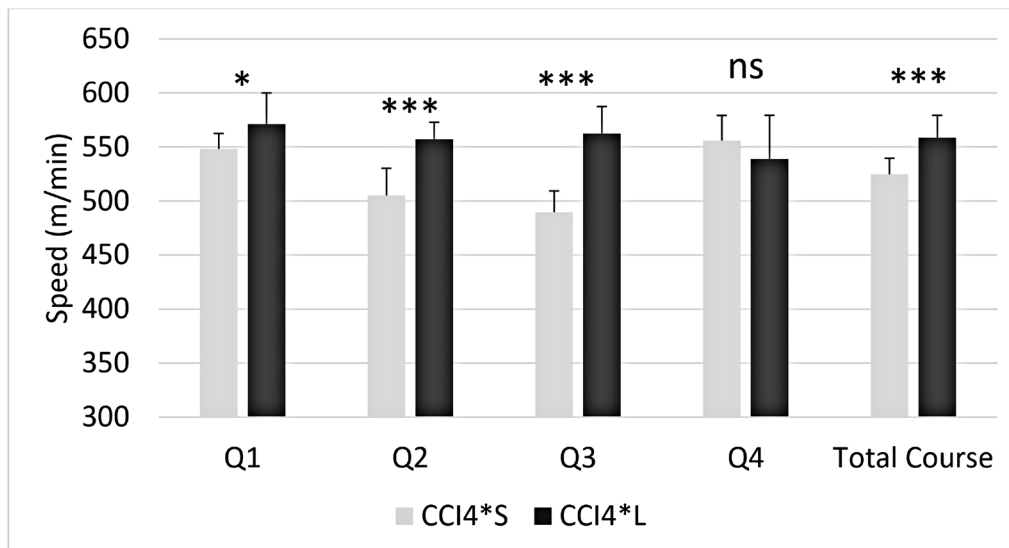


Figure 7: Mean speed ($\pm$ SD) for each quarter of the course (Q1 to Q4) and the total course for horses competing in the CCI4*S (n = 10) and CCI4*L (n = 7). * = $P < 0.05$; *** = $P < 0.001$.

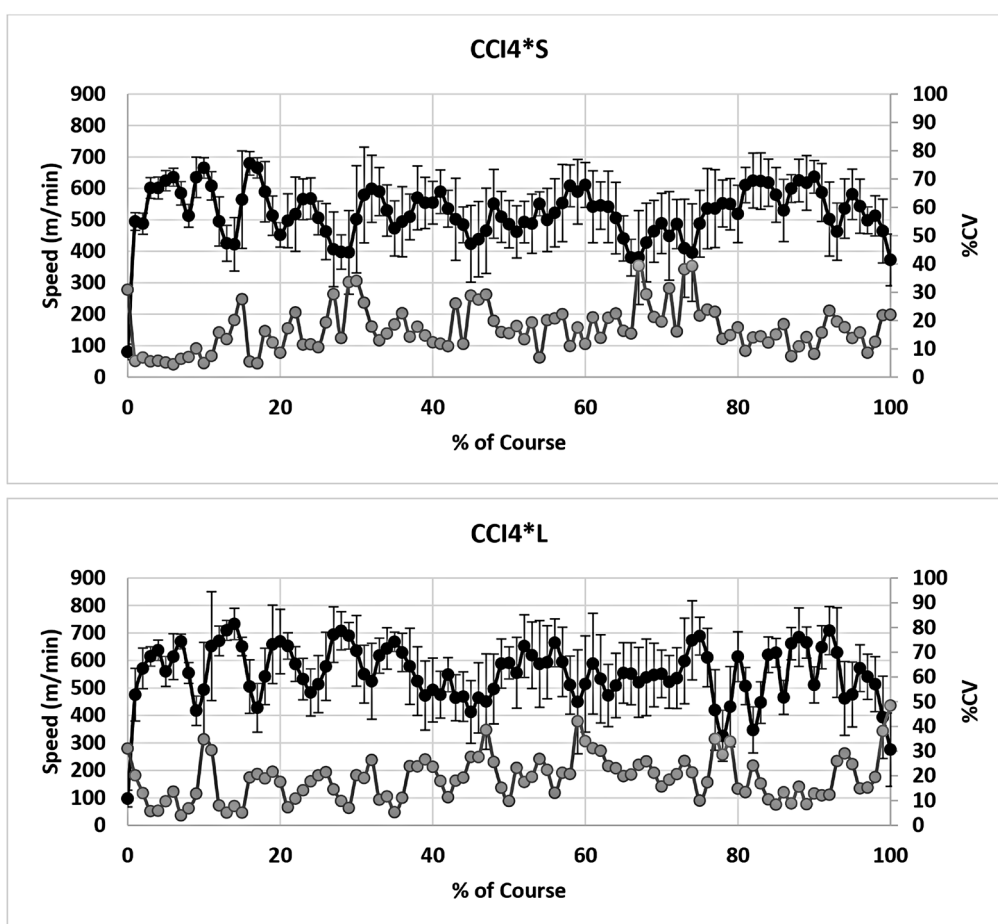


Figure 8: (a, b) Mean $\pm$ SD speed (m/min; black circles) and %CV of speed (SD/mean speed*100; grey circles) as % of course completed for combinations completing the CCI4*S ($n = 10$) and CCI4*L ($n = 7$).

4. Discussion

Riders spent longer warming-up for CCI4*L (~30 min) than CCI4*S (~21 min). However, for both S and L, the majority of warm-up time was spent in walk. The required average speed for S and L was 570 m/min, and only two horses approached that intensity during the warm-up, both in L. In human sport, for most activities, research suggests a warm-up intensity of 50 to 80% of maximal effort or competition intensity, with the lower end for endurance-based sports and the higher end for high-intensity sports, with a duration of 10–20 min with a gradual increase in intensity [1,16–18]. As far as we are aware, there is only one previous report of warm-up duration in eventing [5]. Valle *et al.* [5] recorded speed and heart rate using a Polar Pro Trainer 5 in 5 horses competing in an intermediate 2-day event (Distance: 2,460 m; Speed: 510 m/min; Time: 4:50 min; Fence height: 1.05 m) and 5 horses competing in an advanced 2-day event (Distance: 2,700–3,100 m; Speed: 520–530 m/min; Time: 5:20–5:51 min; Fence height: 1.10–1.15 m). Mean warm-up time was 28 min for both the intermediate and advanced competitions. Mean warm-up speed was 119 m/min and 170 m/min for the intermediate and advanced competitions, respectively, while peak mean warm-up speed was 379 m/min and 433 m/min, respectively. There were no significant differences between intermediate and advanced. Compared with the present study at a higher level, warm-up duration was similar for L (30 min vs 28 min) but shorter for S (21 min vs 28 min).

Warm-up should be used to increase body temperature, which increases aerobic efficiency and to ensure a high degree of splenic contraction, which in turn will increase oxygen uptake kinetics [3]. Warm-up that is of too low an intensity and/or completed too long before the start of competition will be less effective due to failure to sufficiently mobilize red blood cells into the circulation and/or allowing significant re-uptake of red blood cells by the spleen. The time between the last cantering exercise in warm-up and the start of the cross-country did not differ between S and L. Overall, the mean duration was around 5 min, but varied from as little as 0.2 to 10.7 min. If it is assumed that warm-up should be at 80% of competition intensity, then 80% of 570 m/min is equivalent to 456 m/min. However, as mean peak speeds were 638 m/min for CCI4*S and 678 m/min for CCI4*L, this would equate to warm-up speeds of 510 and 542 m/min, respectively. It appears that, on average, less than a few minutes was spent at this intensity for either CCI4*S or L. A typical warm-up for a human athlete for an event at 90–100% VO_2 max and lasting around 10 min might consist of Extended Light Aerobic Activity (5–10 minutes), Dynamic Stretching and Mobility Exercises (5–7 minutes), High-Intensity Intervals (4–6 minutes), and finally Event-Specific Drills (3–5 minutes), with the entire warm-up lasting approximately 15–25 minutes, and concluding the warm-up shortly before the event to maintain the physiological benefits [1,16].

Table 4: Cross-country official distance and time, and Catapult sensor-reported distance, time, and calculated speed and faults for 10 horses and riders competing in the CCI4*S. Horse 11 is not shown as it was retired by the rider at 1400 m into the course.

Class	Rider number	Hold on course	Official distance (m)	Ridden distance from Catapult (m)	Difference (m)	Official time (mm:ss)	Catapult time (mm:ss)	Difference (s)	Catapult average speed (m/min)	Time faults	Jumping penalties
CCI4*S	1	N	3810	3884	74	07:35	07:36	1	512	21.2	20
CCI4*S	2	N	3810	3960	150	07:30	07:31	1	528	19.2	20
CCI4*S	3	N	3810	3869	59	07:03	07:06	3	549	8.4	0
CCI4*S	4	N	3810	3869	59	07:08	07:09	1	542	0	0
CCI4*S	5	N	3810	4119	309	08:08	08:09	1	506	0	40
CCI4*S	6	N	3810	4113	303	07:15	07:17	2	567	0	0
CCI4*S	7	N	3810	3943	133	07:28	07:29	1	528	18.4	20
CCI4*S	8	N	3810	3869	59	07:28	07:30	2	518	0	0
CCI4*S	9	N	3810	3840	30	06:54	06:56	2	557	4.8	0
CCI4*S	10	N	3810	3845	35	07:03	07:04	1	540	0	15
			Mean	3931	121	07:21	07:22	2	535	14.4	12
			SD	105	105	00:21	00:21	1	20	7.3	14
			Min	3840	30	06:54	06:56	1	506	0	0
			Max	4119	309	08:08	08:09	3	567	21.2	40

Table 5: Cross-country official distance and time, and Catapult sensor-reported distance, time, and calculated speed and faults for 7 horses and riders competing in the CCI4*L.

Class	Rider number	Hold on course	Official distance (m)	Ridden distance from Catapult (m)	Difference (m)	Official time (mm:ss)	Catapult time (mm:ss)	Difference (s)	Catapult average speed (m/min)	Time faults	Jumping penalties
CCI4*L	1	N	5885	6067	182	10:20	10:21	1	587	0.0	0
CCI4*L	2	N	5885	6038	153	11:06	11:05	-1	544	18.4	20
CCI4*L	3	Y	5885	6310	425	10:23	10:40	17	608	1.2	0
CCI4*L	4	N	5885	6041	156	11:02	11:04	2	548	16.8	20
CCI4*L	5	Y	5885	6263	378	10:47	10:53	6	581	10.8	11
CCI4*L	6	N	5885	6038	153	10:27	10:28	1	578	2.8	0
CCI4*L	7	N	5885	5961	76	10:10	10:10	0	586	0.0	0
			Mean	6103	218	10:36	10:40	4	576	7.1	7
			SD	131	131	00:21	00:21	6	23	8.1	10
			Min	5961	76	10:10	10:10	-1	544	0	0
			Max	6310	425	11:06	11:05	17	608	18.4	20

Optimal speed and pacing are critical factors in success in many human and equestrian sports, with initial high speed or high variation in speed linked to early elimination or poor performance. The use of inappropriate and highly variable pacing strategies has been associated with poor performance in human endurance running [19–21]. Interestingly,

riders who adopted a more consistent pacing strategy in equine endurance racing were less likely to be eliminated for metabolic- or lameness-related problems [9,10]. In particular, the speed selected to complete loop 1 of races was influential with respect to non-completion for gait-related reasons, with horses whose riders selected unsustainable initial

speeds on loop 1 more likely to subsequently be eliminated due to lameness [9,10]. The overall race strategy, combined specifically with loop 2 pace, appears key to preventing elimination for metabolic reasons. Race speed has previously been related to increased levels of horse elimination in endurance races [22], leading to suggestions that non-completion could be due to owners and riders selecting inappropriate race strategies to facilitate success.

Burger *et al.* [13] reported mean and peak speed between jumps of 583 m/min and 735 m/min for the second minute of the cross-country, respectively, combined for all competitions studied, and 579 m/min and 751 m/min, respectively, for the last minute of the cross-country. These were not significantly different between the second minute and the last minute. In contrast, in the present study, the mean peak inter-fence/combination speed was lower (639 m/min for CCI4*S and 678 m/min for CCI4*L) and significantly greater for the CCI4*L. The reason for the difference between the CCI4*S and CCI4*L may be related to the average distance between jumping efforts of 112 and 144m, respectively, allowing more time for horses to reach a higher peak speed before the need to slow down for the next obstacle. Mean speed at jumps was reported to be 415 m/min and 441 m/min (second and last minute, respectively) and was not significantly different [13] and compares closely to the present study, where mean jump speed over the whole course was 404 m/min for CCI4*S and 393 m/min for CCI4*L and was not significantly different.

With respect to the CCI4* compared with the CCI4*L, in terms of the pacing strategy, riders in the CCI4*L maintained a similar average speed across all 4 quarters of the course, while riders in the CCI4*S slowed from Q1 to Q2 and Q2 to Q3, increasing speed in Q4 to that in Q1. This suggests the horses were not fatigued and that potentially the drop in speed during the middle of the course was likely linked to the nature of the fences, as challenging fences are usually avoided very early and/or very late in cross-country courses. It also suggests that riders may adopt a similar approach at the start and end of the cross-country. In addition, as mentioned above, jumping efforts are more frequent in CCI4*S compared with CCI4*L.

From an applied perspective, riders spend the majority of the time warming up in walk and trot with little, if any, exercise approaching the speeds they will ride at on the course. In terms of common approaches in human sport, this would seem less than optimal. In addition, riders in the present study appear to rapidly accelerate and decelerate rather than attempt a more constant speed. Analysis of cross-country warm-up and competition using wearable technology has the potential to inform coaches and riders on how to optimize strategy to delay the onset of fatigue and ensure clear rounds within the time. Given that of 18 horses monitored, 8 incurred cross-country jumping penalties, 1 retired on course, and 15 received cross-country time penalties, it would appear that there is an opportunity to improve.

4.1. Limitations

Limitations of this study include the relatively small number of horse and rider combinations studied ($n = 18$). It is important to consider that the reported data in this study

are effective for the rider, as the sensor was mounted on the rider. However, as the riders' motion while mounted is only likely to vary imperceptibly from that of the horse, any error in the reported speed of the horse-rider combination will likely be minimal.

5. Conclusion

In conclusion, the present study has demonstrated that the Catapult Vector S7 sensor system is suitable and accurate for determining speed and distance traveled during high-level eventing cross-country competition, including warm-up. In addition, a number of significant differences between CCI4*S and CCI4*L format events were observed, which may suggest riders adopt different strategies for these different events.

Supplementary Materials

Supplementary Materials include maps of the CCI4*S and CCI4*L cross-country courses showing track layout, jump positions, and elevation profiles over distance.

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Authors' Contributions

D.J.M.: Conceptualization, Methodology, Formal analysis, Investigation, Writing – original draft, Writing – review & editing. H.C.W.: Investigation, Data curation, Writing – review & editing. R.M.G.: Conceptualization, Methodology, Investigation, Writing – review & editing. A.L.: Methodology, Formal analysis, Supervision, Writing – review & editing.

Data Availability

Requests for access to the data should be directed to the corresponding author. Reasonable requests to access data will be considered. Certain data may be withheld if it is considered that this could potentially be used to identify individual athletes based on existing information in the public domain relating to the specific event at which the data were collected.

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Conflicts of Interest

Andrew Lombard is employed part-time by Catapult as a consultant. David Marlin and Russell McKechnie-Guire work part-time for Team GB Equestrian. Heather Cameron-Whytock declares no conflicts of interest.

Ethical Approval

Specific ethical approval for this study was not required as the study involved only wearing a commercially available non-invasive sensor by athletes already competing under Team GB, posed no greater risk than routine training or wearing a watch, collected fully anonymized data with no

identifiable private information, aligned with UK Sport/Team GB performance monitoring protocols, and obtained informed consent consistent with event participation and the Declaration of Helsinki, including permission to use the data collected from them and their horses. For the time that the researchers interacted with the horses and riders, any interaction with the horses was conducted in full compliance with the UK Animal Welfare Act 2006, ensuring that all reasonable steps were taken to meet the animals' welfare needs and to prevent any unnecessary suffering, in line with the Act's provisions and the Five Freedoms framework.

Declaration of Generative AI and AI-Assisted Technologies

The authors confirm that no Generative AI or AI-assisted technologies were used in the writing, editing, or preparation of this manuscript. The entire content was authored solely by the individuals listed.

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Demographic Predictors of Chronic Pain in American Equestrians: A Secondary Analysis

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Abstract

Equestrians report a high rate of chronic pain (CP), which can disrupt horse-rider movement patterns, communication, and safety. Equestrian-related risk factors (i.e., participation level) for reporting CP are well established, while demographic predictors remain underexamined in American equestrians. The purpose of this study was to examine demographic predictors of self-reported CP in American equestrians. This study was a secondary analysis of cross-sectional survey data from adult American equestrians ($n = 1,968$) that included self-reported CP status (no formal definition or diagnosis) and demographic variables. All variables were categorical. Chi-square tests ($P < 0.25$) informed forward-selection binary logistic regressions to estimate odds (ORs) of reporting CP across demographic variables, with significance set at $P < 0.05$. Approximately 45% of the sample reported general CP. The sample was predominantly female (96%). Participation level was a significant predictor of reporting general CP and chronic back, pelvic, and lower leg pain, with professionals having 1.71–1.95 greater odds ($P < 0.05$) than recreational equestrians, and 1.39–1.80 greater odds than amateur equestrians ($P < 0.05$). Body mass predicted general CP and chronic back pain, with riders weighing <91 kg having lower odds of reporting general and back CP (ORs = 0.45–0.60, $P < 0.05$). Model discrimination was modest across analyses (c-statistics: 0.58–0.63). Participation level remains significantly associated with reporting. Body mass emerged as a potential predictor, while other demographic predictors (e.g., age and sex) remain uncertain with regard to reporting CP in American equestrians. Future research should examine body mass, riding biomechanics, and joint-specific load distribution across disciplines with consideration of horse and human health.

Keywords

Horseback riding; body mass; risk factors; human-animal interactions; pain prevalence

1. Introduction

Equestrian activities provide a unique form of lifelong physical engagement across a variety of disciplines, each with distinct rules and performance objectives. They are considered an "early-start" and "late-specialization" sport, which supports participation across the lifespan, including childhood development and later career and family phases [1–4]. Equestrian activities are highly inclusive, with males and females competing together across all levels of participation (e.g., recreational, amateur, and professional) [2,3]. Successful riding relies on a high degree of biomechanical

coordination between the horse and rider, such that the rider's posture, balance, and movement directly influence the horse's gait and movement patterns [5–8]. Beyond the physical demands of the sport, participation also involves a human-animal bond that contributes to improved mental, social, and physical well-being [9–11].

Participation in equestrian activities is associated with several benefits, including improved balance, strength, physical well-being, mood, self-esteem, and social connectedness [12–19]. These benefits often coexist with a high risk of acute

and overuse injuries. Horses, as large sentient animals, are responsive to environmental and human stimuli and can behave unpredictably, increasing the risk of injury during riding and handling [20–22]. Equestrians are also susceptible to overuse injuries due to the accumulation of musculoskeletal strain over time from repetitive biomechanical forces during riding and routine barn work [23–28]. The accumulation of repetitive forces and the high risk of acute injuries can lead to long-term health consequences for equestrians.

Such injuries may progress to chronic pain (CP), defined as pain that persists or recurs for more than half of the days per week for three months or longer [29]. CP imposes a substantial societal burden when considering the cost of disability, medical losses, and decreased productivity [30,31]. In the general population, risk factors for CP include age, sedentariness, obesity, manual labor, low socioeconomic status, sleep disturbances, and psychosocial strain [32,33]. One of the most prominent risk factors for chronic musculoskeletal pain is sedentariness (i.e., prolonged waking time spent sitting or reclining), coupled with low engagement in moderate-to-vigorous physical activity (i.e., not meeting physical activity guidelines) [34]. Together, these factors can facilitate weight gain, which is a concern, as obesity also significantly increases the risk of developing chronic musculoskeletal pain [34,35]. Finally, patterns of older-aged individuals and females experiencing a higher prevalence of musculoskeletal pain have surfaced within current literature [33].

Previous studies reveal that 24–87% of equestrians report experiencing CP, with low back pain being the most prevalent [36–43]. This high rate of CP in equestrians is not only concerning from a human health perspective, but also from a horse welfare and safety standpoint. Balance and coordinated movement patterns are essential for communication between the horse and rider [44–48]. Equestrians experiencing CP may adopt compensatory movement patterns that alter posture and loading on the horse's back, which could negatively impact equine movement and welfare [49]. Therefore, understanding potential risk factors that increase the rate of CP in equestrians is critical to both horses and humans.

Studies have identified that participation level, discipline, hours spent riding, barn chores, and saddle fit are related to overuse injuries, acute pain, and CP in equestrians [26,36–41,43,50,51]. Across the literature, participation levels consistently emerge as a strong and reliable factor relating to acute pain and CP, with professionals reporting a higher frequency of pain than recreational and amateur riders [43,52,53]. While participation level and other equestrian-related risk factors provide important context, identifying demographic patterns of CP is a critical step that remains underdeveloped in the equestrian literature.

Previous work has yielded inconsistent findings regarding demographic risk factors for reports of pain in equestrians. With respect to age, one study identified younger riders at greater risk of reporting low back pain, while others have reported a higher risk among older riders [53,54]. Two studies specifically report that riders over 35 years old are most likely to report experiencing pain [37,39]. In contrast, one study reported no association between age and pain [38]. While

studies report varying findings, the balance of evidence suggests a trend toward greater reporting of pain with increasing age, similar to that observed in the general population.

Evidence regarding sex differences is similarly mixed. Lewis and Baldwin [37] reported that female event riders were more likely than males to report pain, a pattern echoed in later work showing that females were more likely to have experienced pain in the previous two years than their male counterparts [37,39]. Another study also found a higher risk of low back pain among females [55], whereas Ferrante *et al.* [53] reported no association between sex and low back pain. Despite some inconsistency, findings more commonly indicate higher pain reporting among female equestrians.

Anthropometric characteristics (e.g., height, body mass, and body mass index (BMI)) have likewise produced contradictory findings. Some studies have found no associations between anthropometric variables and reporting pain and pain-related functional limitations [25,53,54,56,57]. However, other studies have reported that higher BMI and body mass are associated with greater pain-related disability and an increased risk of low back pain across the lifespan [53,54,56,57]. Taken together, there is some evidence to suggest that greater body mass may be associated with increased pain risk. Considering these inconsistencies, which are derived predominantly from European samples, it is critical to examine demographic factors associated with reporting CP in American equestrians.

The general American population exhibits higher obesity rates, lower physical activity engagement, and worsening mental health trends compared to many European countries [58,59]. In this context, understanding how demographic risk factors relate to self-reported CP in American equestrians is crucial for identifying targets for prevention and early intervention to decrease CP rates. American equestrians represent a wide range of individuals across the lifespan. Identifying demographic factors associated with CP is a critical step toward improving long-term participation, safety, and overall well-being. Therefore, the purpose of this study was to examine demographic predictors of self-reported CP in American equestrians. We hypothesized that (1) participation level would be significantly associated with reporting CP, with professionals at greater risk of reporting general and regional CP, and (2) equestrians with higher body mass, who were female, and were of older age would be at greater risk of reporting general and regional CP.

2. Methods

2.1. Study Design and Data Source

Data collected and stored from a cross-sectional survey in 2020–2021 were leveraged for a secondary analysis of demographic variables and their associations with self-reported CP. The original dataset was used to evaluate physical activity across participation level [17] and to assess the relationships between self-reported acute injury and CP status across participation level [43]. The data have also been used to evaluate relationships between physical activity engagement and reporting CP in equestrians [60]. These data analyses were approved by the University of Kentucky's Institutional Review Board under protocol number 56488.

2.2. Dataset Inclusion and Validation

The current study used a new set of inclusion criteria compared to the previous studies [17,43,60]: included responses were from (1) active equestrians 18 years or older, (2) who completed the CP section of the survey, and (3) provided definitive answers for demographic and CP questions (e.g., not "prefer not to answer").

2.3. Questionnaire Details

All variables extracted for the secondary analysis were categorical. Questions included general demographics that determined sex, height, body mass, region of the United States (US), race, and age. Questions regarding equestrian participation included the participation level (professional, amateur, and recreational), number of years spent participating in equestrian activities, how often they engaged in equestrian activities in the 6 months prior to taking the survey (monthly, 1–2 days/week, 3–4 days/week, 5–6 days/week, or daily), and if they participate year-round (Y/N). Professional equestrians were defined as individuals receiving payment for riding/training/grooming. Amateur equestrians were defined as individuals who are competitive but do not receive financial compensation. Recreational equestrians were defined as individuals who engage in noncompetitive activities [17]. If they selected "no" to whether they participated year-round, branching logic asked them to select which seasons they engaged in equestrian activities. Finally, individuals were asked if they currently experience any CP (Y/N) without a formal definition or diagnosis. If they selected "yes", then they were asked to select all the anatomical regions they experience pain in, with the options including head/face, neck, chest, back, breasts, abdomen, arms, hands, pelvis, genitals, upper leg, lower leg, and feet.

2.4. Data Cleaning

Data cleaning and analysis were completed in SAS 9.4. The original dataset comprised 2,579 initiated responses. Based on the inclusion criteria, data from 115 minors (younger than 18 years old) were excluded, 416 individuals were excluded for not completing the CP section, and 79 were excluded for not providing definitive responses to key items (including missing data). Following data cleaning, data were examined for duplicates ($n = 0$) and response validity, which included checking for implausible values, such as participants reporting years of experience in equestrian activities greater than their age ($n = 1$). The final dataset for this analysis included 1,968 responses.

To address categories with sparse counts, response categories were generally collapsed to preserve ordinal structure and to satisfy standard assumptions for contingency analyses (i.e., ensuring that at least 5% of the sample contributed to each combined category). Two variables warranted exceptions to this 5% rule. For height, collapsing all categories with fewer than 5% of responses would have reduced six levels to only two, eliminating meaningful distinctions and limiting interpretability. Instead, we collapsed low-frequency categories at the shortest and tallest ends of the distribution, acknowledging that the resulting categories still did not reach the 5% threshold. Similarly, for years of equestrian experience, there were low frequencies in the two categories representing ≤ 5 years of experience. Rather than combining these

with a third category and creating an overly broad grouping of <10 years of experience, we collapsed only the two categories to retain a more meaningful distinction for early years of equestrian activity. **Table 1** presents the frequencies and percentages for each category before and after collapsing.

For individuals who did not report riding year-round, a variable was created by summing the number of seasons in which they reported riding (range: 1–3). Participants who indicated riding in all four seasons were reclassified into the "yes" (participates in equestrian activities year-round) category.

Table 1: Frequency and percentage of responses in categories before and following collapsing.

Pre-collapsing categories			Post-collapsing categories		
	n	%		n	%
Age (y)					
18–24	283	14.3	18–24	283	14.3
25–29	227	11.4	25–29	226	11.4
30–34	222	11.2	30–34	222	11.2
35–39	216	10.9	35–39	215	10.9
40–44	161	8.1	40–44	161	8.1
45–49	120	6.0	45–49	120	6.1
50–54	146	7.4	50–54	146	7.4
55–59	146	7.4	55–59	146	7.4
60–64	204	10.3	60–64	204	10.3
65–69	147	7.4	65–69	146	7.4
70–74 ^A	88	4.4	≥70 ^A	112	5.7
≥75 ^A	26	1.3			
Height (cm)					
<137 ^A	5	0.3	<152 ^A	33	1.7
137–150 ^A	28	1.4	152–165	1010	51.0
152–165	1011	50.9	168–180	877	44.3
168–180	878	44.2	≥181 ^B	61	3.1
183–196 ^B	61	3.1			
≥197 ^B	3	0.2			
Body mass(kg)					
<45 ^A	9	0.5	<57 ^A	264	13.3
45–56 ^A	256	12.9	57–68	618	31.2
57–68	618	31.1	68–79	533	26.9
68–79	533	26.8	79–90	319	16.1
79–90	320	16.1	91–102	146	7.4
91–102	148	7.5	≥103 ^B	101	5.1
103–113 ^B	55	2.8			
114–124 ^B	20	1.0			
125–136 ^B	17	0.9			
≥137 ^B	10	0.5			

Pre-collapsing categories			Post-collapsing categories		
	n	%		n	%
Years of experience in equestrian activities (y)					
<1 ^A	5	0.3	<5 ^B	52	2.6
1–4 ^A	48	2.4	5–9	125	6.3
5–9	125	6.3	10–14	203	10.3
10–14	203	10.2	15–19	263	13.3
15–19	263	13.2	20–24	255	12.9
20–24	256	12.9	25–29	218	11.0
25–29	218	11.0	30–34	221	11.2
30–34	221	11.1	35–39	128	6.5
35–39	128	6.5	40–44	103	5.2
40–44	104	5.2	45–49	100	5.1
45–49	100	5.0	≥50	313	15.8
≥50	315	15.9			

Superscript letters (A, B) demonstrate categories combined from the pre-collapsing categories and their respective post-collapsing categories.

2.5. Statistical Analysis

All analyses were conducted in SAS 9.4. Statistical significance was defined as $P < 0.05$. Frequencies and descriptive statistics were calculated for all variables. Correlations among ordinal variables were evaluated using Kendall's Tau correlation coefficients.

Associations between demographic variables and (1) participation level, (2) reporting any CP (general CP), and (3) reporting CP in specific anatomical regions (regional CP) were examined using chi-square tests. Chi-square analyses were conducted only when at least 80% of cells had expected counts of ≥ 5 . Using this criterion, regional CP analyses were only completed for the back, pelvis, neck, upper leg, and lower leg, while the other eight regions did not have high enough counts to run analyses. These regional analyses evaluated reporting CP (Yes/No) across demographic variables. All demographic variables (including collapsed variables) met chi-square assumptions except for race and the number of seasons ridden if not riding year-round.

For general CP and the five regional CP outcomes, variables with $P < 0.25$ in chi-square analyses were entered into the forward-selection binary logistic regression models, consistent with purposeful selection approaches [61]. Variable retention for models was set at $P < 0.05$. The dependent variable in each model was reporting CP (general or regional), coded with "yes, experiencing CP" as the reference category so that odds ratios (ORs) reflect the increased or decreased likelihood of reporting CP. Model results are reported as ORs with 95% confidence intervals (95% CIs) and P -values for retained variables, along with the c-statistic (area under the receiver operating characteristic curve).

The Akaike Information Criterion (AIC) provides a measurement of overall model fit while penalizing the complexity of the predictor variables added. AIC is dataset-specific and does not provide interpretable results without comparison to other models from the same dataset. Therefore, we provide AIC_{Reduction} (AIC_R), which provides a value comparing the models with added variables relative to the null model, defined as $AIC_R = AIC_{null} - AIC_{model}$. The values of AIC_R should be interpreted such that larger positive values indicate greater improvement over the null model, while 0 indicates no improvement, and negative values indicate worse fit compared to the null model. To aid interpretation, we also present ORs from significant models using alternative reference groups, as specified in the results.

3. Results

The final dataset included 1,968 American adult equestrians. The sample was predominantly female (96.0%) and Caucasian (94.0%), with representation across all adult age ranges and regions of the US. Professionals comprised 20.1% of the sample, while amateur (39.1%) and recreational (40.8%) equestrians were evenly represented. Most participants (87.7%) engaged in equestrian activities on a year-round basis. Among those who did not ride year-round, 91.4% reported participating in three seasons per year, with the majority indicating they did not participate during the winter. Regarding riding frequency in the past 6 months, 17.5% of participants reported riding inconsistently (only riding monthly), while the remaining 82.5% reported riding each week consistently. Nearly half of the sample (44.9%) self-reported experiencing general CP, and the most frequently reported region of CP was the back (27.1%), followed by the pelvis (10.1%), lower leg (9.2%), neck (9.1%), and upper leg (7.2%). No other region had a percentage greater than 5% of the sample, and therefore, no other models were run for these regions. Among the 884 individuals reporting CP, 49.5% reported experiencing CP in one anatomical region, 26.7% in two regions, 12.8% in three regions, and 11.0% in four or more regions. **Table 2** presents the frequencies and counts for sex, age, height, body mass, equestrian engagement, and general and regional CP by participation level with chi-square results.

Kendall Tau correlations revealed only three significantly correlated ordinal variables with a $|\tau| \geq 0.20$. Age had a weak negative correlation with participation level of $\tau = -0.21$, $P < 0.001$, meaning that as age increased, the level of participation decreased from professional (3) to recreational (1). Age also had a strong positive correlation with years of equestrian experience, with $\tau = 0.55$, $P < 0.001$. Body mass and height showed a weak positive correlation, with $\tau = 0.30$, $P < 0.001$.

3.1. Chronic Pain Models

For general CP, participation level ($P = 0.0001$), body mass ($P = 0.0002$), sex ($P = 0.161$), experience in equestrian activities ($P = 0.249$), and year-round participation ($P = 0.106$) fell within the $P < 0.25$ cutoff used in the binary logistic regression. The final binary logistic regression model retained participation level ($P = 0.0001$), body mass ($P = 0.0002$), and sex ($P = 0.0086$) as significant predictors for reporting general CP. The overall fit of the model, including both predictors, was significantly better than the

intercept-only (null) model (likelihood ratio $\chi^2(7) = 49.7$, $P < 0.0001$; $AIC_R = 33.71$), with modest model discrimination (c-statistic = 0.58). Forest plots depict ORs and 95% CIs that are presented in **Figure 1** for participation level and **Figure 2** for body mass categories. Professionals were more likely to report general CP than both amateur and recreational riders, whereas there was no significant difference in the likelihood of reporting general CP between recreational and amateur equestrians. Riders weighing <91 kg were less likely to report general CP than those weighing ≥ 91 kg. Females had 1.91 greater odds of reporting general CP than males (95% CI: 1.17–3.12, $P = 0.01$).

Table 2: Frequencies and counts for self-reported demographics, anthropometric characteristics, equestrian engagement details, and chronic pain by participation level in equestrian activities. *P*-values represent results of chi-square tests between the variable and participation level, with significance set at $P < 0.05$.

	Recreational		Amateur		Professional		P-value
	n	%	n	%	n	%	
Sex							
Female	750	97.5	772	96.1	368	92.9	<0.01 [*]
Male	19	2.5	31	3.9	28	7.1	
Age (y)							
18–24	53	6.9	159	19.8	70	17.7	<0.01 [*]
25–29	75	9.8	76	9.5	73	18.4	
30–34	74	9.6	84	10.5	63	15.9	
35–39	76	9.9	86	10.7	52	13.1	
40–44	56	7.3	69	8.6	34	8.6	
45–49	46	6.0	48	6.0	25	6.3	
50–54	65	8.5	54	6.7	26	6.6	
55–59	68	8.8	61	7.6	16	4.0	
60–64	109	14.2	76	9.5	18	4.6	
65–69	79	10.3	55	6.9	10	2.5	
70+	68	8.8	35	4.4	9	2.3	
Height (cm)							
<152	9	1.2	17	2.1	7	1.8	<0.01 [*]
152–165	416	54.1	412	51.3	173	43.7	
168–180	326	42.4	355	44.2	192	48.5	
≥181	18	2.3	19	2.4	24	6.1	
Weight (kg)							
<57	90	11.7	120	14.9	53	13.4	0.06
57–68	229	29.8	252	31.4	134	33.8	
68–79	213	27.7	224	27.9	92	23.2	
79–90	128	16.6	121	15.1	67	16.9	
91–102	55	7.2	58	7.2	31	7.8	
≥103	54	7.0	28	3.5	19	4.8	
Participates in equestrian activities year-round							
No	148	19.3	70	8.7	24	6.1	<0.01 [*]
Yes	621	80.8	733	91.3	372	93.9	
Number of seasons individuals participate in, if not year-round							
1	7	0.9	2	0.3	1	0.3	NA
2	9	1.2	4	0.5	0	0.0	
3	131	17.0	64	8.0	23	5.8	

	Recreational		Amateur		Professional		P-value
	n	%	n	%	n	%	
Engagement frequency on average over the past 6 months							
Monthly	235	30.6	73	9.1	36	9.1	<0.01 [*]
1–2 days/week	194	25.2	138	17.2	38	9.6	
3–4 days/week	253	32.9	336	41.8	116	29.3	
5–6 days/week	78	10.1	226	28.1	126	31.8	
Daily	9	1.2	30	3.7	80	20.2	
Experience chronic pain							
No	450	58.5	453	56.4	181	45.7	<0.01 [*]
Yes	319	41.5	350	43.6	215	54.3	
Experience chronic back pain							
No	590	76.7	583	72.6	261	65.9	<0.01 [*]
Yes	179	23.3	220	27.4	135	34.1	
Experience chronic pelvic pain							
No	702	91.3	730	90.9	337	85.1	<0.01 [*]
Yes	67	8.7	73	9.1	59	14.9	
Experience chronic neck pain							
No	705	91.7	735	91.5	349	88.1	0.10
Yes	64	8.3	68	8.5	47	11.9	
Experience chronic lower leg pain							
No	717	93.2	723	90.0	348	87.9	<0.01 [*]
Yes	52	6.8	80	10.0	48	12.1	
Experience chronic upper leg pain							
No	711	92.5	755	94.0	361	91.2	0.17
Yes	58	7.5	48	6.0	35	8.8	

*Indicates a statistically significant chi-square test ($P < 0.05$).

Participation level ($P = 0.0004$), body mass ($P = 0.001$), engagement frequency ($P = 0.052$), sex ($P = 0.034$), geographical region ($P = 0.194$), and year-round participation ($P = 0.237$) met the cutoff to be entered into the chronic back pain model. The final forward-selection binary logistic regression model retained participation level ($P = 0.0001$), body mass ($P = 0.0001$), and sex ($P = 0.002$) as significant predictors for chronic back pain. The final model, including participation level, body mass, and sex, showed adequate fit compared to the intercept-only (null) model (likelihood ratio $\chi^2(7) = 35.1$, $P < 0.0001$, $AIC_R = 30.5$). Model discrimination was modest (c-statistic = 0.59). Forest plots depicting ORs and 95% CIs are presented in **Figure 1** for participation level and in **Figure 2** for body mass categories. Females were at 2.67 greater odds of reporting chronic back pain than males (95% CI: 1.43–4.97, $P = 0.002$). ORs were significant between all participation levels ($P < 0.05$). Similar to our general CP results, individuals in the lower body mass categories were less likely to report chronic back pain than those in the higher body mass categories.

Participation level ($P = 0.002$), age ($P = 0.008$), sex ($P = 0.136$), body mass ($P = 0.134$), and years of experience ($P = 0.152$) met

the cutoff for the chronic pelvic pain model. Participation level ($P = 0.002$) and age ($P = 0.008$) were retained in the final model to predict experiencing chronic pelvic pain, and showed adequate fit compared to the intercept-only model (likelihood ratio $\chi^2(12) = 36.3$, $P = 0.0003$, $AIC_R = 12.3$). Model discrimination was modest (c-statistic = 0.63). Forest plots depicting ORs and 95% CIs are presented in **Figure 1** for participation level. Professionals were at greater odds of reporting chronic pelvic pain than amateurs and recreational equestrians, while there was no significant difference in odds between amateurs and recreational equestrians. There was no clear-cut age range that demonstrated an increased risk of reporting chronic pelvic pain. Compared to individuals 18–24 years old (y/o), those who were 35–39 y/o had 1.76 (95% CI: 1.01–3.07) greater odds, and those 65–69 y/o had 1.95 (95% CI: 1.04–3.64) greater odds of reporting chronic pelvic pain. Similarly, compared to those who were 25–29 y/o, participants who were 35–39 y/o (OR: 2.28, 95% CI: 1.22–4.26), 50–54 y/o (OR: 2.3, 95% CI: 1.16–4.55), and 65–69 y/o (OR: 2.52, 95% CI: 1.26–5.02) were at greater odds of reporting chronic pelvic pain.

Forest Plot for Odds of Reporting Experiencing Chronic Pain by Participation Level in Equestrian Activities

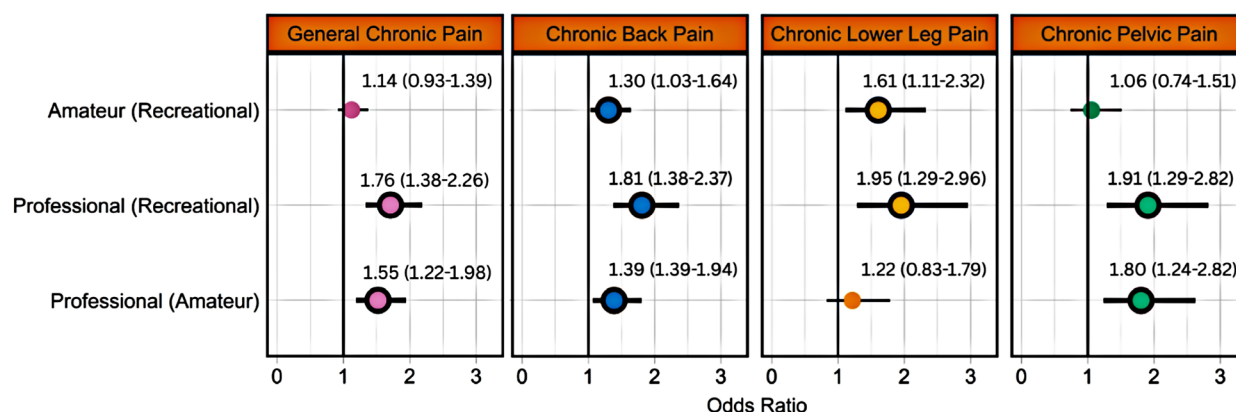


Figure 1: Forest plots depict odds ratios (colored circles) and 95% confidence intervals (horizontal bars) for reporting "yes" to experiencing each chronic pain (CP) outcome (general CP, chronic back, lower leg, and pelvic pain) in relation to participation level in equestrian activities. Significant odds ratios are represented by bolded lines and circles ($P \leq 0.05$). For each row, the group listed first is compared with the reference group in parentheses. For example, data should be interpreted as "Amateurs have 1.3 higher odds of reporting chronic back pain than recreational equestrians."

Forest Plot for Odds of Reporting Experiencing Chronic Pain by Body Mass (kg) in Equestrians

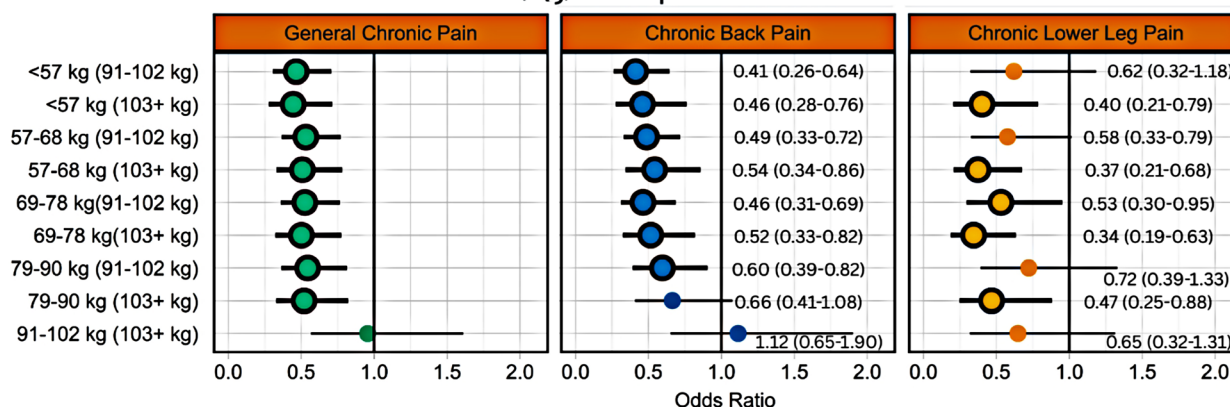


Figure 2: Forest plots depict odds ratios (colored circles) and 95% confidence intervals (horizontal bars) for reporting "yes" to experiencing each chronic pain (CP) outcome (general CP, chronic back, and lower leg pain) in relation to body mass (kg). Significant odds ratios are indicated by bolded lines and circles ($P \leq 0.05$). For each row, the group listed first is compared with the reference group in parentheses. For example, data should be interpreted as "Equestrians reporting they weigh <57 kg were 53% ($1.0 - 0.47 = 0.53$) less likely to report experiencing general CP than those weighing 91-102 kg."

For chronic lower leg pain, participation level ($P = 0.006$), body mass ($P = 0.011$), age ($P = 0.097$), and height ($P = 0.205$) met the cutoff to be included in the model. The final binary logistic regression model retained both participation level ($P = 0.006$) and body mass ($P = 0.005$) with adequate fit compared to the intercept-only model (likelihood ratio $\chi^2(7) = 24.4$, $P = 0.001$, $AIC_R = 10.4$). The model also demonstrated modest model discrimination (c-statistic = 0.61). Forest plots depicting ORs and 95% CIs are presented in **Figure 1** for participation levels, and in **Figure 2** for body mass categories. Professionals and amateurs were at greater odds

of reporting chronic lower leg pain than recreational riders, with no difference between professional and amateur equestrians. Individuals weighing <90 kg were less likely to report lower leg pain than those weighing ≥ 103 kg.

For chronic neck pain, participation level ($P = 0.099$) and sex ($P = 0.10$) met the cutoff to be included in the model. No variables were maintained in the binary logistic regression model for reporting chronic neck pain. Similarly, for chronic upper leg pain, participation level ($P = 0.171$) was the only variable that met the cutoff, and no variables were maintained in the binary logistic regression model.

4. Discussion

This study examined demographic risk factors associated with self-reported CP among adult American equestrians. We hypothesized that participation level would be significantly associated with reporting CP, with professionals at higher odds of reporting general and regional CP than amateur and recreational equestrians. This hypothesis was supported in the current study for general CP and chronic back, lower leg, and pelvic pain. Our second hypothesis was that equestrians with higher body mass, who were female and of older age, would have higher odds of reporting general and regional CP. Body mass was significantly associated with reporting general CP, chronic back pain, and chronic lower leg pain, with heavier individuals being more likely to report CP than lighter individuals. Sex was associated with general CP and chronic back pain, with females at greater odds of reporting chronic back pain than males. However, sex differences were not identified in general or other regional CP. Despite a significant association between age and chronic pelvic pain, greater odds were not confined to a specific age range. As foundational information, these data represent participants across the US, the adult lifespan, and participation levels. While the current study provides foundational information regarding demographic factors associated with reporting CP in American equestrians, these findings should be interpreted with consideration of the study's limitations. These include the use of a pre-existing dataset for secondary analysis, the absence of a standardized definition of CP in the original survey, and modest model discrimination across analyses, indicating a limited ability to distinguish between participants who did and did not report experiencing CP.

The current study aligns with previous literature supporting that professionals have a greater likelihood of reporting CP than recreational and amateur equestrians. This relationship was identified for general CP and chronic back and pelvic pain. Participation level consistently emerges as a key factor associated with CP in equestrians. Financially, professionals rely on training horses, managing boarding facilities, providing lessons and clinics, and working in numerous environments as their primary income. Therefore, their higher odds of reporting CP are associated with greater cumulative exposure to equestrian demands [12,17,23,24,62]. Higher workload increases musculoskeletal stress and the risk of developing overuse injuries and CP in regions such as the low back, pelvis, and shoulder [40,63,64]. As a primary source of income, professionals lack the ability to reduce or modify workload to accommodate pain, which may contribute to the higher reports of CP in this group. Research in other occupational settings reports that the flexibility to modify work tasks is positively associated with reduced levels of disability related to CP and recurrence of CP [65]. Notably, the current study indicates that participation level remains a significant predictor of reporting CP after accounting for demographic and anthropometric characteristics. The elevated reports of CP in professionals across the literature, paired with the current study's findings, highlight the need for future research to focus on the occupational demands and environmental settings (i.e., arena type, stable design, equipment, frequent travel, etc.) [66–69].

Participation level also reflects both the number and the training level of horses ridden regularly [17]. Younger, "greener" horses, defined as horses with limited training and inconsistent responses, are more likely to react unpredictably to environmental stimuli and rider cues [20,21,70,71]. While performing these job demands, professionals are more likely to ride greener horses than amateurs and recreational equestrians, creating a greater risk of acute injury [27,72–76]. A majority of equestrians who have sustained a severe equestrian-related injury report experiencing long-term health impacts, including CP [64]. Consistent with this pattern, experiencing a previous acute injury increased the odds of reporting CP in the same region across most anatomical sites in equestrians [43,52]. Finally, equestrian culture is known for the minimization of human injury, including disregarding injury completely, not seeking medical attention, and not adhering to rehabilitation, all of which could be heightened for professionals who rely on equestrian activities as their primary income [43,77–80]. Financial stress is a key motivator for individuals to continue working despite pain [80–82]. Taken together, the current study extends and reinforces prior work by demonstrating that participation level remains a significant and independent contributor to reports of CP.

Within the equestrian community, the body mass of the rider is commonly discussed in relation to the health, welfare, and movement of the horse [83–85]. Most CP research in equestrians has focused on anthropometric measures in relation to back pain, as this is the most reported region for CP. However, the association between body mass and chronic back pain remains inconsistent across the literature [26,36–40,53,54]. One study reported similar findings to the current study, with body mass being associated with reports of low back pain episodes across the participants' lifetime in Italian equestrians [53]. However, the same study reported no relationship between body mass and experiencing low back pain in the past year [53]. Similar findings are echoed in another study comprised of Portuguese equestrians [54]. While the current study did not collect information regarding BMI, one study reported that increased BMI was associated with higher disability scores [54]. Taken together, the variability between the current and previous studies likely reflects differences in study design, measurement approaches, definitions (or lack thereof) of CP, and how anthropometric variables were captured.

An important divergence between the current study and prior work is the difference in body mass distributions. Previous literature reported an average body mass between 60.1 and 76.5 kg for both females and males [53,54]. When extrapolating the reported body mass ranges based on reported means and standard deviations, these samples only marginally approach the 91 kg threshold identified in the current sample. In contrast, our study collected body mass categorically and included a larger body mass range, with ~15% of the current sample reporting body mass >91 kg. Although the use of categories is a limitation in terms of measurement precision, it offers practical advantages by reducing social desirability bias related to self-reported body mass. Individuals are generally more willing to select an accurate range than to provide an exact number, particularly if they perceive their body mass to fall outside of socially desirable norms [86]. This tendency

may be amplified within equestrian sports, as some equestrian disciplines rely heavily on aesthetic-based scoring and the body mass of the rider is often discussed in terms of horse welfare [5,87–90]. With consideration of the categorical approach and modest model discrimination, the observed associations between body mass and CP should be interpreted with appropriate caution, as these associations likely capture only a portion of the factors contributing to CP in equestrians.

Differences in body mass between the current sample and those in previous studies likely arise from two main factors: national obesity rates and equestrian participation level. Prior work has focused on European equestrians, who come from populations with lower national obesity rates than the United States (e.g., 15.8–23.7% in Italian adults vs. 40.3% in U.S. adults) [91,92]. These differences suggest that a larger proportion of individuals who meet diagnostic criteria for obesity may be engaging in equestrian activities in the United States than in some European countries. Two recent studies evaluating body mass and pain were distributed through national equestrian federations and therefore likely over-represent competitive, registered riders, whereas the current study included equestrians outside these structures [53,54]. As a result, earlier findings may be less generalizable to recreational riders who are not members of a national federation and may experience less pressure related to aesthetic-based scoring. With consideration of these differences, the present study suggests a potential body mass threshold at which CP may increase in a broader, more recreational equestrian population.

Understanding how body mass may influence CP is critical, particularly given its direct implications for equine welfare [93]. Prior work demonstrated that a higher rider-to-horse body mass ratio and rider position in the saddle (which changes with body mass) can impair equine gait and increase the risk of lameness occurring [94]. The study emphasized the importance of future research to quantify rider body weight and anthropometric characteristics (e.g., leg and torso length), as they alter weight distribution, balance, and dynamic loading on the horse's back [93,94]. When a rider is heavier and experiencing CP, it is plausible that the rider uses compensatory movement patterns, which may exacerbate asymmetrical movement and load distribution on the horse. This concern is further supported by research in the general population demonstrating that individuals with low back pain exhibit greater asymmetry in pelvic and trunk motion while sitting and standing compared to individuals without low back pain [95]. Synthesizing findings from previous and current work reveals the vitally important direction of future research in examining how body mass, CP, and asymmetrical movement of the rider influence the horse.

The current study identified a relationship between body mass and reporting chronic lower leg pain. While lower-extremity pain is not commonly reported in equestrian literature, show jumpers reported experiencing pain most frequently in the back (62%), knee (47%), and ankle (36%) [38]. While our survey design precluded joint-specific and discipline-specific comparisons, previous research supports that different disciplines and riding styles (i.e., rising versus sitting trot) impose distinct biomechanical demands on the lower extremities and spine [13,28,38,47,96,97]. Based on the literature, the mechanical demands of different riding styles

may help explain the observed association between body mass and lower-extremity pain and inform targeted prevention strategies. Therefore, future research should examine joint-specific CP across equestrian disciplines.

While the sample collected in this study included a substantially higher proportion of female than male participants, it is broadly representative of the national American equestrian population [55,98,99]. Current literature in the general population reveals that females are disproportionately impacted by CP compared to males [33,100]. Specifically, higher rates of chronic low back pain and chronic neck pain are observed in females [33,100,101]. Within the equestrian population, a recent systematic review reveals inconsistent findings regarding sex differences in relation to back pain [26]. One study evaluating amateur equestrians reported that females are at a higher risk of reporting low back pain compared to males [55]. In contrast, two studies of Italian and Portuguese equestrians found no association between sex and low back pain [26,53]. In the current study, sex was associated with chronic back pain and general CP. However, these findings should be interpreted with caution, given the substantial imbalance in sex distribution, which limits variability, reduces statistical power to detect differences in males, and may result in unstable estimates.

Female equestrians reporting higher rates of experiencing chronic back pain may reflect a combination of anatomical, physiological, and psychological factors, although these interpretations remain speculative. For example, females have a higher prevalence of scoliosis in the general population, which may influence spinal alignment during riding [102]. Non-neutral spinal alignment resulting from scoliosis or anterior pelvic tilt in the saddle could plausibly affect force attenuation and increase susceptibility to persistent pain. Psychological factors, such as depression and anxiety, are associated with chronic low back pain in the general population [103,104]. Rates of anxiety and depression are higher in females, which may contribute to the sex differences observed in the current study [105]. However, these variables were not assessed in the current study, and their role in equestrian populations is unclear. While equestrian activity has been associated with mental health benefits [14,15,18,19], future studies should evaluate how both psychological risk factors and potential protective effects of riding interact to influence CP within this population.

Older age is often associated with increased risk of experiencing CP, due to joint deterioration, muscle weakening, and reduced engagement in physical activity [33]. In the current sample, older age was not consistently associated with a higher likelihood of reporting general or regional CP. Prior work indicates that aging equestrians maintain or exceed age-matched normative grip strength, suggesting that continued engagement in horse-related activities may support musculoskeletal function across the lifespan [16]. Maintaining grip strength in older adults is linked to better quality of life, greater independence in daily activities, and reduced risk of disability [106–108]. Collectively, these findings suggest that continued equestrian participation may support musculoskeletal health. However, aging and its relationship with reporting CP remain unclear based on the current findings, and

future work should focus on longitudinal health implications and benefits of engaging in equestrian activities.

The literature examining age and CP in equestrians remains inconsistent, in part due to variability in how acute and chronic pain are defined and measured [26]. Few studies use a formal definition of CP, defined as pain present for more than half of the days in the past three months, to determine the presence of CP [29]. One study that used this definition also examined the number of episodes of low back pain across multiple time frames (e.g., past 1 month, 3 months, 6 months, 1 year, and lifetime) and reported conflicting findings [53]. Younger age was associated with lifetime and one-year incidence of low back pain, but not with chronic low back pain within the same cohort [53]. Another study reported higher pain intensity ratings among equestrians aged 18–35 years compared with those over the age of 36, although this difference was not statistically significant [37].

Contrary to previous findings, one study identified older age as a risk factor for low back pain–related disability among riders who had experienced low back pain in the past 12 months [54]. However, the effect size was modest, with a 10-year increase in age corresponding to only a 1-point increase on the Roland–Morris Disability Questionnaire. The small magnitude of this effect and the complexity of the analytical model make direct comparison with the current study difficult. Notably, the same study found no significant association between age and the likelihood of reporting low back pain in the past 12 months [54]. Additional studies fail to clarify this relationship, as they report limited or no consistent associations between age and back pain outcomes, including prevalence, pain intensity, and disability [109]. Given the modest model discrimination observed in the current study, age-related findings should be interpreted with caution, as these models do not fully capture the factors influencing the reporting of CP. As current literature remains inconclusive, future research should explore age-related participation factors, including participation level and workload, which may provide clearer insight than aging itself.

4.1. Limitations

The current study relies on self-reported CP status rather than requiring a formal diagnosis from a healthcare provider. Additionally, participants were not provided with a standardized definition of CP or asked to describe their pain (i.e., pain rating intensity, interference with daily activities, etc.). These limitations could result in participants reporting CP without meeting diagnostic criteria, whereas others who met criteria may not have identified themselves as having CP. Furthermore, insight into the pain experience of American equestrians cannot be inferred from the information gathered in the current study. Since anatomical selections provided were based on regions rather than joints, participants may have experienced confusion when choosing which region to select for joint pain. For example, it may have been unclear to participants whether to select either the pelvis or the upper leg region, or both regions, when experiencing chronic hip pain. These factors limit the generalizability of the current study. Regardless, the current study provides valuable data on

the relationship between body mass and CP in equestrians, especially in a group with a large recreational proportion.

While the dataset comes from a convenience sample collected online, the sample's demographics aligned with those reported in the last American Horse Council report [110]. With consideration of the alignment in demographics and the current study having a distribution across the adult lifespan and from all regions of the US, including Hawaii and Alaska, it provides meaningful information and highlights areas for future research. Due to participants being able to self-select multiple disciplines, we were unable to determine discipline-specific relationships, which limits the insights available into reporting differences between disciplines. This limitation may have minimal impact as equestrians often shift between disciplines throughout their lifespan.

4.2. Future Research

The current study highlights areas for future research to further evaluate risk and protective factors for experiencing CP in equestrians, especially within the American equestrian population. Future studies should focus on evaluating the body mass of equestrians regarding CP development and persistence, and how the combination of body mass and CP might impact rider movement asymmetry and thereby negatively impact horse welfare. Considering the current study adds to contradictory findings regarding demographic risk factors and reporting CP, future research should utilize standardized definitions of pain, clearly define recall periods, distinguish between recurring episodes of pain versus the presence of CP, and use multidimensional pain questionnaires. A greater focus on modifiable factors associated with the development and maintenance of CP in future research is likely to facilitate implementable strategies to address the high prevalence of CP within the equestrian population.

5. Conclusion

The findings of the current study provide a new perspective on CP risk factors regarding demographics in equestrians by evaluating a large nationwide sample, including all levels of equestrian participants. American equestrians reported a lower prevalence of chronic back pain than some European samples. The current study reports that higher body mass categories (>91 kg) were associated with greater odds of reporting general and region-specific CP (back and lower leg). These findings suggest a potential threshold effect; however, this should be interpreted as a preliminary association that requires confirmation in studies using continuous measures of body mass, rather than categorical data. Additionally, given the cross-sectional design and modest model discrimination, these associations should not be interpreted as strong or independent predictors. Engagement in equestrian activities across the lifespan may be associated with improved musculoskeletal health in older adults; however, its relationship with CP cannot be determined from the current data. Our study's findings represent preliminary associations of potential risk factors related to reporting CP rather than causal relationships. Additional research is needed to confirm our findings, particularly using longitudinal designs and continuous variables to elicit more detailed relationships. In addition, future research should focus on evaluating the relationships between body mass, CP, and movement patterns in equestrians and how these factors influence horse movement and welfare.

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Authors' Contributions

E.A.O.: Conceptualization, Methodology, Formal analysis, Writing – original draft, Writing – review & editing, Project administration. K.I.T.: Conceptualization, Data curation, Writing – review & editing. M.M.K.: Conceptualization, Methodology, Formal analysis, Writing – original draft, Writing – review & editing, Project administration.

Data Availability

The datasets analyzed during the current study are not publicly available due to institutional review board restrictions, but are available from the corresponding author upon reasonable request.

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Conflicts of Interest

The authors declare that there are no conflicts of interest.

Ethical Approval

This study has been approved by the Institutional Review Board at the University of Kentucky, protocol number 56488. This study has followed the guidelines of the Declaration of Helsinki.

Declaration of Generative AI and AI-Assisted Technologies

During the preparation of this work, the authors used ChatGPT (GPT-4o, OpenAI) sparingly for minor sentence level-editing (e.g., rephrasing). Following the use of this tool, the authors reviewed and edited the content as needed and take full responsibility for the final version of the publication.

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The Immediate Effect of Pole Work and Kinesiotape on Engagement of Rectus Abdominis and Longissimus Dorsi Activity, Pelvic Symmetry, and Kinematics in Horses

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Abstract

This study investigated the acute effects of ground poles and abdominal kinesiotaping (KT) on rectus abdominis (RA) and longissimus dorsi (LD) muscle activity, pelvic symmetry, and selected kinematic variables in eleven horses trotting in hand. Four conditions were evaluated: control, poles, KT, and combined KT with poles. Surface electromyography quantified muscle activity, inertial sensors assessed pelvic symmetry, and two-dimensional video analysis measured limb protraction and lumbosacral (LS) angle. Peak RA activity was significantly greater during poles and poles with KT compared with KT alone ($P \leq 0.003$), although average RA activity did not differ between conditions. LS angle was reduced during poles at forelimb midstance ($P = 0.035$) and at maximal hindlimb protraction ($P \leq 0.023$). Hindlimb protraction decreased in pole conditions ($P < 0.001$). No significant effects were observed for LD activity or pelvic symmetry. These findings indicate that pole exercise influences abdominal muscle activation and lumbosacral kinematics during trot. Kinesiotaping alone did not significantly alter muscle activity or kinematics. The magnitude and clinical relevance of observed changes were modest, and the potential influence of speed cannot be excluded. Further controlled studies incorporating three-dimensional kinematics and velocity measurement are warranted.

Keywords

Cavaletti; core; biomechanics; strengthening; taping

1. Introduction

Core strength is vitally important for maintaining effective locomotion, with evidence that core function correlates significantly with equine performance. In accordance with the "bow and string theory," epaxial and hypaxial muscles, such as *M. longissimus dorsi* (LD) and *M. rectus abdominis* (RA), counteract ground reaction forces (GRF) and stabilize the vertebral column with gait progression [1–6]. Since the strength of the muscular chain depends on its weakest link, it is vital to understand its function and explore strengthening techniques. Pole exercise is commonly used to encourage increased limb flexion and trunk engagement, whereas

kinesiotaping is proposed to modulate neuromuscular activation via cutaneous stimulation. Although both interventions are independently used in rehabilitation settings, their combined acute effects on trunk muscle activity and lumbosacral kinematics have not been investigated. If kinesiotaping (KT) enhances abdominal activation, it may potentiate the mechanical demands imposed by poles. Conversely, its effect may be negligible when a mechanical stimulus is already present.

Due to the scarce scientific evidence on muscular activity during movements for rehabilitation [7,8] and the challenge of targeting an isolated set of muscles in the horse, global

trunk-strengthening approaches are favored [9]. These often combine the use of various training aids, including Pessoa and poles [10,11]. Previous research [12] has found that the increase in LD activity over ground poles was not significant bilaterally, possibly highlighting the role of LD in lateral bending [13]. The same study reported activity of RA when walking and trotting over ground poles. Similarly, an increase in RA activity while trotting over poles using surface electromyography (sEMG) [14] was found.

The use of elastic bands is becoming very popular in rehabilitation settings. These bands aim to encourage hindlimb engagement and support recruitment of RA [12]. Similar to the abdominal band, stimulation of mechanoreceptors using KT is beginning to attract scientific interest, but its effects require further investigation [15–17].

Kinesio taping is thought to affect five systems: skin by decompression; fascia by redirecting movement; muscle via function optimization; lymphatic system through fluid redirection; and joints via proprioceptive awareness and muscle control [18]. The effects on kinematics and muscular activity have been minimally investigated in the equine sample. Still, the rich innervation of equine sensory receptors may account for effects across multiple layers [16,18] and consequently affect neuromuscular activity [18,19]. KT may be beneficial in abdominal engagement through the response from *M. cutaneus trunci* and its fascial connections with the underlying musculature [20]. However, only two studies have thus far implemented abdominal taping. A previous KT study [15] examined its effect when applied to the abdomen with no stretch, on the kinematics of the thoracolumbar spine in eight trotting horses using video analysis. Although no significant change in kinematics was observed, the activity of taped muscles was not measured. Abdominal KT increases longitudinal activity, decreases stride frequency, and thus potentially lengthens the stride [16]. The researchers explained this as a hypothetical increase in eccentric abdominal contractions during the stance phase, resulting in increased lumbosacral (LS) flexion, which provided the rationale for examining LS kinematics in the present study.

Furthermore, LS flexion was found to correspond with hindlimb protraction [6], which was also associated with desirable core and hindlimb engagement [21]. Lastly, trotting over poles increased flexion in all joints, consequently affecting protraction and retraction of both the forelimbs and hindlimbs, making it a relevant parameter for the current study [22].

This study investigated the effect of poles and KT applied to the abdomen on the LD and RA activity, LS angle, pelvic symmetry, and forelimb and hindlimb protraction and retraction angles. It was hypothesized that (1) poles would increase RA and LD activation and improve kinematics; (2) kinesiotaping would independently increase RA and LD activation, and kinematic parameters would be improved; and (3) combined application would produce summative effects.

2. Methodology

This study was designed and reported in accordance with the ARRIVE 2.0 Essential 10 guidelines [23] to ensure transparent and reproducible animal research.

2.1. Ethical Statement

The current study was approved by the Ethical Committee at Writtle University College (number: 98379136/2023). The study was carried out in accordance with guidance on the operation of the Animals (Scientific Procedures) Act 1986 and associated guidelines. The welfare of all animals was monitored according to a strict protocol, and any distress or decline in condition would result in exclusion from the experiment and appropriate veterinary attention. Fresh water for horses was provided throughout the data collection. Written consent was obtained from all owners of the horses participating in the study.

2.2. Horses

Eleven school horses (seven geldings and four mares of various breeds in light- to medium-work) were used for the study; mean $\pm$ SD age was 12 ± 4.5 years, and height at the withers was 156 ± 4.5 cm. The selection criteria excluded horses with a history of back pain/pathologies or with signs of pain and lameness; young horses; and horses not trained or unable to perform pole work. The sample size was calculated using the resource equation approach and power analysis. The sample size of eleven horses was deemed sufficient in similar published studies assessing sEMG in horses performing therapeutic exercises, which achieved adequate statistical discrimination with a range of four to six horses [12,24]. Assuming the methods differ slightly in their interventions and outcomes, with estimates differing by 10%, with Type I and Type II errors of 0.05 and 0.20, respectively, using the Bland-Altman test, we estimated that a sample size of between 5 and 12 horses was needed (MedCalc® Statistical Software version 20.115). Due to the extent of this study, a larger number of horses was chosen to account for possible equipment failures and to enable comparison with preceding studies [16]. The study cohort was standardized by selecting riding school horses in regular, light- to medium-work prior to data collection, which ensured a consistent fitness level and a moderate body condition score. These inclusion criteria controlled for variations in subcutaneous adipose tissue and muscle hypertrophy that can affect sEMG signals. Borderline BCS, muscular atrophy, or prominent asymmetry were factors that led to exclusion from the study, as well as any signs of lameness or underlying health condition during the screening process by a veterinary professional. The breed composition consisted primarily of Warmbloods, with a Thoroughbred, a Paint Horse, and a draft-cross, which ensured the results were representative of the general school horse amateur riding population.

2.3. Experimental Setup

Five wooden poles (10 cm cross-section, 1.2 m long) spaced at $120 \text{ cm} \pm 5 \text{ cm}$ apart were placed perpendicularly to the long axis of a harrowed arena with a soft synthetic surface [12]. Pole spacing was adjusted by $\sim 5 \text{ cm}$ to accommodate the individual horse [12]. The high-speed camera, set to record at 240 fps, was positioned 8 m away from the trot-up area.

All horses were fitted with their usual bridle (two with a Micklem bridle, eight with an English snaffle bridle with a cavesson noseband without flash, and one with a flash). Horses were warmed up for 10 minutes (8 minutes of walking, 2 minutes of trot evenly on each rein, including walking and trotting over flat poles to habituate them to the exercise). For all conditions, horses were fitted with inertial measurement units (IMUs), sEMG electrodes, and reflective markers. For the tape condition, KT was applied as per [16]. Horses were trotted in hand from the left side in a marked straight line at their natural, consistent speed. The same handler was used to ensure consistency. Five successful trials were retained for data analysis for each horse in each condition. Data were not collected if the horse lost straightness or made an obvious gait alternation, and trials were deemed successful only if the horse stepped over the poles cleanly with a consistent speed and rhythm. The randomized conditions were:

- (1) Without kinesiotape, straight line.
- (2) Without kinesiotape, straight line over ground poles.
- (3) With kinesiotape, straight line.
- (4) With kinesiotape, straight line over the ground poles.

2.4. Kinesiotape Application

The targeted muscles were the RA and the obliquus externus abdominis (OEA) [16]. Marks were drawn bilaterally at the following anatomical locations: paralumbar fossa (ventrally to the tuber coxae); behind the girth at the level of the olecranon to tape the RA; further on, at the caudal ends of *M. pectoralis ascendens*; and on the ventral midline at the level of the 18th rib to tape the OEA.

Six-cm-wide pieces of adhesive KT (Vetkin, THYSOL Group B.V., Enschede, NL) were attached with ~25% stretch in the direction of the muscle fibers (Figure 1). The ends of the tape were attached without stretch to the marked point on the skin for better adhesion [16].



Figure 1: Tape application at 25% stretch (ventral view).

2.5. Kinematics Data Collection and Analysis

Six 3D, 30 mm diameter spherical reflective markers were secured using double-sided adhesive tape. For limb kinematics, markers were placed on the scapular spine tuberosity, the ventral border of the tuber coxae, and the mid-lateral aspect of the forelimb and hindlimb coronary bands. For LS kinematics, markers were placed at L6 and the greater trochanter of the femur, creating an angle with the highest point of the withers [25]. Before data analysis, calibration was performed in the motion analysis software using a video of horizontal and vertical lines. Calibration was performed prior to each data collection session using a standardized one-meter reference object. Although formal intra- and inter-session calibration reliability testing was not conducted, consistent camera positioning and environmental conditions were maintained.

Horses were recorded perpendicular to a single high-speed video camera mounted in a level position on a tripod (determined by a tubular spirit level), approximately 8 m from the horse, with one LED spotlight (500 W) to illuminate the reflective markers. The camera collected data at 240 Hz (resolution: 1,334 × 750 pixels, 720p HD), with a field of view that captured at least one full stride during trot.

Motion analysis software (Quintic Biomechanics v.34, Quintic Consultancy Ltd., Birmingham, UK) was used to analyze each video. The forelimb protraction and retraction angles were determined as vertical angles using markers on the scapular spine and the coronet band at the maximal points of protraction and retraction (Figure 2). The hindlimb protraction and retraction angles were determined by the tuber coxae and hindlimb coronet band at maximal hindlimb protraction and maximal hindlimb retraction. The greater trochanter, L6, and the highest point of the withers defined the LS angle. To reduce within-horse variability, measurements from three strides per trial and horse were averaged. Lumbosacral angulation was measured at four points of the stride [25]: forelimb midstance, hindlimb protraction, hindlimb midstance, and hindlimb retraction. Midstance was identified as the metacarpus/metatarsus being perpendicular to the ground [26].

2.6. Surface Electromyography (sEMG) Data Collection and Analysis

Muscle activity data collection and analysis followed the methodology described previously [27]. Surface electromyographic signals were acquired using a dual-channel sEMG system (Neurotrac MyoPlus 2 Pro, Verity Medical Ltd., Hampshire, UK). The device operated over a continuous amplitude range of 0–2000 μ V root mean square (RMS) within a frequency band of 2–100 Hz, with pulse widths of 50–450 μ s and a sensitivity of 0.1 μ V RMS (4% accuracy; readings $\pm$ 0.3 mV at 200 Hz). The sEMG equipment used utilizes a fixed internal gain with a wide band-pass filter of 18 fHz to 370 Hz (for readings below 235 μ V) or 10 Hz to 370 Hz (for readings above 235 μ V). These parameters align with sEMG protocols previously reported in equine studies [27]. A 50 Hz notch filter and a high common-mode rejection ratio (130 dB) were employed to minimize environmental electrical noise and motion artifacts.

Manufacturer-supplied software (Neurotrac, Verity Medical Ltd., Hampshire, UK) was used to quantify activity in the left rectus abdominis (RA) and left lumbar longissimus dorsi (LD).

For electrode placement, hair was clipped over the lumbar region of the left LD (between L3 and L4) and caudal to the sternum for the left RA. Hair was removed from each site using clippers (No. 40 clipper blade) [28], and then the skin was prepared with surgical spirit to remove grease and debris and optimize electrode contact. All clipping was performed by the same investigator (AS) to ensure consistency among horses. A pair of pre-gelled electrodes (50 × 50 mm) was positioned 5 cm lateral to the spine at the left lumbar level (L3–L4). A second pair was placed 2 cm lateral to the linea alba, caudal to the sternum, over the left RA belly. The inter-electrode distance was 1 cm, which lies within the range reported in previous equine sEMG studies. A reference electrode was positioned over the left tuber coxae. Peak and mean muscle activity (μV) were extracted for each condition (Figure 3).

Raw sEMG signals were differentially amplified with a common-mode rejection ratio of 130 dB and processed with band-pass filters of wide (18 ± 4 Hz cut-off) and narrow (370 ± 10 Hz cut-off) bandwidths, as well as a 50 Hz notch filter. Outcome variables comprised the average rectified value (ARV) and peak sEMG for each muscle under all conditions, with exercise duration used as the temporal domain.

Outliers in ARV were identified and excluded using thresholds set at two standard deviations above or below the mean ARV for each horse, muscle, and condition, following the approach described in equine sEMG research [29]. For peak sEMG, outliers in the baseline recordings before normalization were detected and subsequently removed. Signals were normalized to muscle activity obtained while the horse stood square, enabling comparison with values recorded during exercise.

2.7. Pelvic Symmetry Data Collection and Analysis

Pelvic symmetry data were collected and analyzed in accordance with the protocol described in equine research [30]. A commercially available inertial sensor system (Equinosis Q Lameness Locator, Missouri, USA) comprising three sensors ($3.8 \times 2.5 \times 1.3$ cm; mass 30 g) was used. Sensors were secured to predefined anatomical landmarks following the manufacturer's guidelines: the poll (head bumper), the midline between the tubera sacrale (pelvic mount with adhesive bandage), and the dorsal aspect of the right forelimb pastern (limb strap).

Data were sampled digitally at 200 Hz in real time and processed using proprietary software supplied by the manufacturer (Equinosis Q Lameness Locator, Missouri, USA). Signals from the pelvic and poll accelerometers were analyzed using a custom error-correcting double-integration method, while the right forelimb gyroscope signal was used to determine stride segmentation. Uniaxial acceleration data from the pelvic sensors were converted into displacement traces, from which two maxima and two minima were identified per stride.

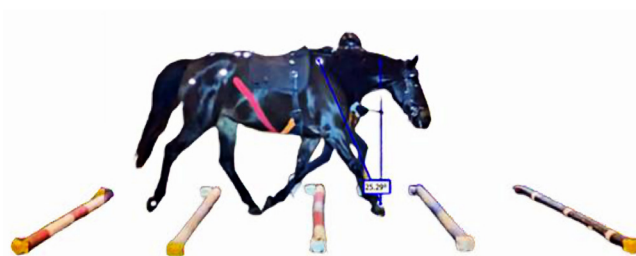


Figure 2: Data collection field with conditions "tape and poles" showing the angle from the vertical using the spine of scapula and coronet band markers to determine maximal forelimb protraction.

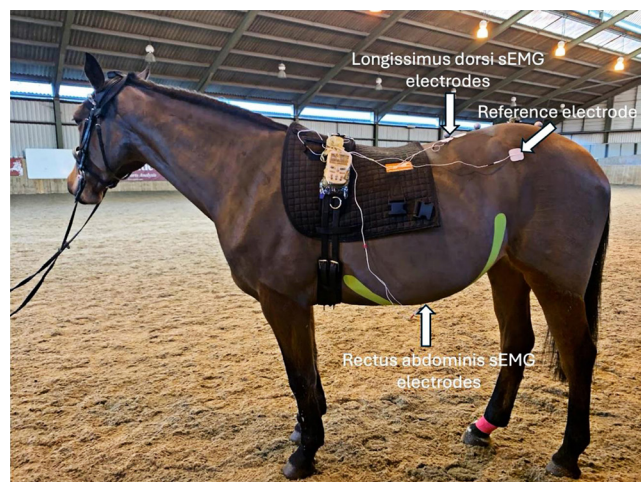


Figure 3: Positioning of sEMG electrodes (wires visible).

For each stride, the difference in minimum pelvic height between left and right stance phases (PDmin) and the difference in maximum pelvic height following left and right stance phases (PDmax) were calculated. Values exceeding a threshold of ± 3 mm were interpreted as asymmetry; positive values indicated right hindlimb asymmetry, and negative values indicated left hindlimb asymmetry. To quantify pelvic asymmetry independent of direction, PDmax and PDmin values associated with the left hindlimb were converted to absolute (positive) values to permit direct comparison with right hindlimb measurements.

2.8. Statistical Analysis

Following analysis of the sEMG signals, all data were recorded in Microsoft Excel spreadsheets (Microsoft Excel Office 365, Redmond, Washington, USA) and transferred to Jamovi (version 2.6) for further statistical analysis. The Shapiro-Wilk test was used to determine normality. A one-way repeated-measures ANOVA test was used for normally distributed data with Greenhouse-Geisser (ϵ) correction when data violated the assumption of sphericity on Mauchley's test, and a Friedman's test was used for non-normally distributed data to discover any significant differences between conditions. Significance was established at $P < 0.05$. For each significant finding, post hoc analysis with a Tukey correction for repeated-measures ANOVA and Durbin-Conover for Friedman's test was performed to determine pairwise differences between conditions. For parametric tests, data are presented as mean $\pm$ standard deviation, and for non-parametric tests, data are presented as median (Mdn).

3. Results

Full sets of data were collected for all horses with the exception of average and peak activities for LD for two horses, which were excluded from the sEMG analysis due to inconsistency in readings. Parametric data are reported as the mean $\pm$ standard deviation, and non-parametric data are presented as the median (IQR Q1, Q3).

3.1. LD and RA Muscular Activity

The average activity of RA increased from Mdn = 44.36 μ V (IQR 28.6, 107) with no intervention to Mdn = 62.96 μ V (IQR 46.9, 104) with tape and poles, then to Mdn = 69.30 μ V (IQR 42.1, 103) with poles only, and finally to Mdn = 75.56 μ V (IQR 31.9, 170) with tape only; however, the differences were not statistically significant ($\chi^2(3) = 1.36$, $P = 0.714$). On the contrary, there was a significant difference in the peak activity of RA between conditions ($\chi^2(3) = 12.40$, $P = 0.006$). In the pairwise comparisons, there was a statistically significant increase with poles only (Mdn = 529 μ V (IQR 330, 623)) and tape with poles (Mdn = 498 μ V (IQR 362, 594)) compared with tape only (Mdn = 271 μ V (IQR 166, 542)) ($P < 0.001$ and $P = 0.003$, respectively) (Figure 4).

Neither the average ($\chi^2(3) = 2.73$, $P = 0.435$), nor the peak activity ($F(3,24) = 0.155$, $P = 0.926$, $\eta^2p = 0.019$) of LD was statistically significantly different under different interventions.

3.2. Lumbosacral Angle

Lumbosacral angulation was measured at four points of the stride, from which a statistically significant difference was found at forelimb midstance and hindlimb protraction (Figure 5). LS angle at forelimb midstance was significantly different between conditions ($F(3,30) = 4.27$, $P = 0.013$, $\eta^2p = 0.299$). LS angle at forelimb midstance was significantly decreased with poles ($147 \pm 6.05^\circ$) when compared with no intervention ($150 \pm 5.59^\circ$) (-2.93° (95% CI, -3.82° to -2.04°), $P = 0.035$). LS angle at maximal hindlimb protraction was statistically significantly different between conditions ($F(3,30) = 7.88$, $P < 0.001$, $\eta^2p = 0.441$). It decreased with poles ($146 \pm 5.67^\circ$) and poles and tape ($145 \pm 5.16^\circ$) when compared with no intervention ($149 \pm 5.38^\circ$) (-2.91° (95% CI, -3.74° to -2.09°), $P = 0.023$) and (-3.58° (95% CI, -4.40° to -2.76°), $P = 0.006$, respectively). Neither the LS angle at hindlimb midstance ($F(1.86,18.62) = 3.28$, $P = 0.063$, $\eta^2p = 0.247$) nor at maximal hindlimb retraction ($F(3,30) = 0.792$, $P = 0.508$, $\eta^2p = 0.073$) was statistically significant with different interventions.

3.3. Pelvic Symmetry

No statistically significant difference was found for both the pelvis difference minima ($PD_{\min}$) ($F(3,30) = 0.314$, $P = 0.815$, $\eta^2p = 0.030$) and pelvis difference maxima ($PD_{\max}$) ($F(3,30) = 0.231$, $P = 0.874$, $\eta^2p = 0.023$).

3.4. Limb Kinematics

Hindlimb protraction was statistically significant under different interventions ($P = 0.000152$) (Figure 6). Pairwise comparisons revealed statistically significant differences in hindlimb protraction between conditions ($\chi^2(3) = 20.2$, $P < 0.001$). Tape alone had increased hindlimb protraction (Mdn = 11.06 $^\circ$) compared with tape and poles (Mdn = 9.44 $^\circ$) ($P < 0.001$) and poles only (Mdn = 9.38 $^\circ$) ($P < 0.001$). Furthermore, no intervention (Mdn = 10.2 $^\circ$) had higher hindlimb protraction than poles alone ($P < 0.001$) and tape and poles ($P < 0.001$), showing that poles reduced protraction in general. The results showed no significant effects for the following: forelimb protraction ($\chi^2(3) = 2.45$, $P =$

0.484); forelimb retraction ($F(3,30) = 2.40$, $P = 0.088$, $\eta^2p = 0.193$); and hindlimb retraction ($F(3,30) = 0.724$, $P = 0.546$, $\eta^2p = 0.067$).

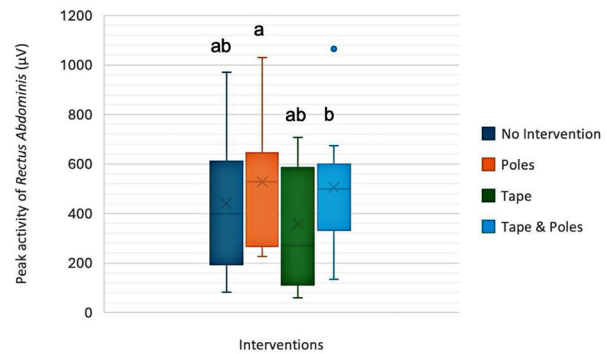


Figure 4: Peak rectus abdominis activity (V) for 11 horses trotting over ground (no intervention), over poles, with kinesiotape only, and over poles with kinesiotape. The boxplot displays the first (bottom) and third (top) quartiles, with the median shown as a band and the mean indicated by an x. Whiskers represent the minimum and maximum values. Significant differences are denoted by * for $P < 0.05$ and ** for $P < 0.01$.

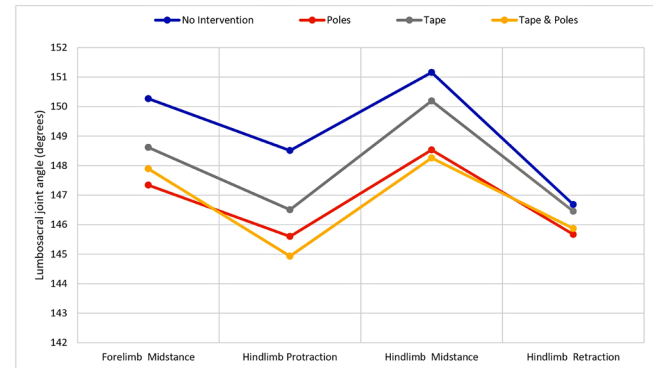


Figure 5: Linear graph displaying mean LS angle (degrees) at four points of the stride (forelimb midstance, hindlimb protraction, hindlimb midstance, and hindlimb retraction) for different interventions. The graph illustrates a significant increase in LS flexion at forelimb midstance for poles ($P = 0.049$) and at hindlimb protraction for poles ($P = 0.032$) and tape and poles ($P = 0.008$) compared with no intervention.

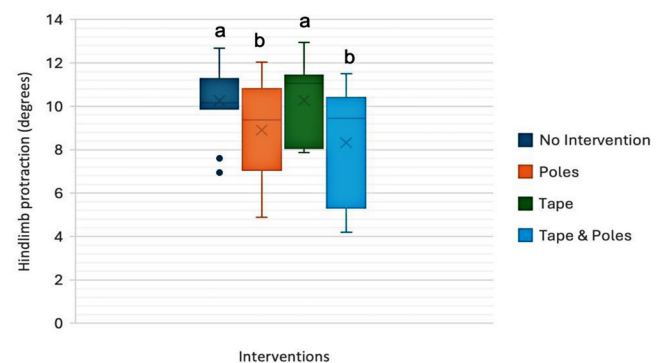


Figure 6: Hindlimb protraction ($^\circ$) for 11 horses trotting over ground (no intervention), over poles, with kinesiotape only, and over poles with kinesiotape. The boxplot displays the first (bottom) and third (top) quartiles, with the median shown as a band and the mean indicated by an x. Whiskers represent the minimum and maximum values. Significant differences are denoted by different letters.

4. Discussion

The experimental hypotheses can be partially accepted, as significant changes were found in the peak activity of RA, in the LS angle at forelimb midstance and hindlimb protraction, and in hindlimb protraction.

Shaw *et al.* [12] reported larger bilateral electrical activity peaks in RA, corresponding to an increased abdominal response to ground poles at both walk and trot. This is in agreement with the findings of the present study, indicating that poles may be beneficial in abdominal engagement [12,14]. However, current findings reflect brief contractions rather than a sustained increase in average abdominal activity.

Despite researchers suggesting that poles are beneficial for strengthening, there is a lack of evidence on the mechanisms behind muscle activation and poles, with previous research [22] reporting no increase in vertical trunk excursion, suggesting that to clear the poles, increased flexion in the limb joints is required. Such a mechanism was observed in earlier pole studies [22,31,32]. Anatomically, achieving a higher flight arch to clear the obstacle requires an increase in concentric contractions of all limb flexors. Moreover, a speed reduction was reported over poles [22,31,32], which could account for the general increase in muscular effort, particularly within the flexor chain.

The antagonist interaction between LD and RA [1–4], in accordance with the "bow and string" theory [33], keeps the spine stable while opposing increasing forces. Several researchers reported a linear increase in RA activity with speed [1,3,34], which may suggest that with gait progression, RA plays a more important role in maintaining spinal stability than LD [8]. While another study [35] argued that LD activity appears to be correlated with speed on a straight line, there seems to be variability in response to different training aids. For instance, it has been reported that there was greater LD activity in the control group compared to side reins and Pessoa [10], while reduced LD activity was observed with the abdominal band at walk and trot [12]. Accordingly, caution is advised when implementing the abdominal band, due to the potential reduction in epaxial activity [24].

Unlike in jumping, LD activity is not required to increase suspension over poles. Instead, it continues to stabilize the skeleton during limb flexion over poles [22,36]. It could be argued that the lack of significant change in epaxial activity in this study could indicate flexor chain activation, observed in peak RA activity, associated with desirable hindlimb engagement [37].

Nevertheless, LD was only analyzed for nine out of eleven horses due to the inconsistency of sEMG readings, which may have had an impact on the results. Moreover, the present research included only sound horses, whereas the activation pattern of LD shows significant variability in lame horses [38].

The abdominal resistance band, similarly to KT, is thought to stimulate mechanoreceptors embedded in the underlying tissue [9,15,18]. Using an abdominal band, research found a statistically significant increase in the peak activity of the left RA (unilateral findings may reflect a lateral bias, associated with paired muscular groups [39]). Due to the richer

innervation of equine skin with sensory receptors [18], an increase in muscular activity could therefore be expected as a response to tactile stimulation by KT [20]. Despite the average RA activity being highest with tape among other conditions, current results do not support this assumption. Moreover, the results are not directly comparable with previous studies on abdominal taping [15], which used a different taping approach and did not assess muscular activity, while other studies [16], despite applying a similar technique, interpreted kinematic changes as a result of increased abdominal activity without monitoring muscular activity. On the contrary, given that peak RA activity was lowest in the tape condition, KT may have facilitated a more consistent average muscular response in this study.

The LS angle was measured at four points of the stride as per previously published research [25]. A marginally significant difference was reported at forelimb midstance for poles, where the LS angle was reduced compared with the no-intervention group. A further significant difference was found at maximal hindlimb protraction, where the LS angle decreased with poles and further with tape and poles when compared with the no-intervention group.

In the present study, both poles alone and tape combined with poles increased LS flexion. This change was observed at the maximal protraction of the stride, corroborating previous findings [6], which reported that the maximal LS flexion occurs during hindlimb protraction. The marginally significant increase in LS flexion at forelimb midstance may represent a pre-phase before hindlimb protraction, when the limb is accelerating over the pole, and LS flexion starts to increase. Considering that an increase in abdominal activity was seen in the pole condition, the current findings may support the proposed association of the LS angle with abdominal activity [16].

The combination of tape and poles did not appear significantly different from poles only. Although the LS angle did not reach statistical significance for the tape condition, a numerical difference was observed, but this should therefore be interpreted with caution. This may be explained as a minor response from *M. cutaneus trunci* to tactile stimulation and its fascial connections with the underlying RA [20], causing a kinematic response. Limited changes may also link to the diagonal nature of the trot, which is likely to limit the LS angulation in comparison to non-symmetrical gaits [6].

Data from inertial sensors showed no significant difference in minimum or maximum pelvis differences, showing that none of the interventions negatively affect pelvic symmetry. Inertial sensors are not commonly used in studies examining poles or abdominal tape, except for one study [31], which found a significant reduction in craniocaudal movement of the tuber sacrale and coxae and an increase in mediolateral motion when horses moved over poles. However, no evidence of pelvic symmetry was provided, which makes further comparisons challenging.

In accordance with the statistical analysis, the only significant result for limb kinematics was found in hindlimb protraction, which was most prominent with KT, followed by the no-intervention group, when compared with either pole condition.

Maintaining a full range of motion (ROM) is a common goal in rehabilitation, and an increase in protraction, associated with desirable core and hindlimb engagement, is often sought after in equine athletes [21]. Increased hip flexion was reported when trotting over poles [22], and suggested that poles would be beneficial in restoring hindlimb protraction. Despite the expected positive correlation among hindlimb protraction, abdominal activity [1], and LS flexion [22], a reduction in hindlimb protraction may suggest that the chosen pole spacing was limiting hindlimb protraction, although it has not limited LS flexion. This agrees with recently reported findings [40] that protraction/retraction was reduced at shorter pole distances and suggested implementing shorter pole distances in cases where limiting spinal extension is a priority. Previously reported reduction in speed over poles [22,31] may also have contributed to changes in hindlimb kinematics in the present study [41].

Previous KT research [16] observed a decrease in stride frequency, thus, potential lengthening of the stride with KT under its influence. Nevertheless, there was no statistically significant difference in hindlimb protraction between the no-intervention and KT group. Although abdominal taping may not significantly promote limb kinematics in this study, the results suggest that the current KT application was not restrictive to limb kinematics, as opposed to poles in this research.

Our study was not without limitations. Firstly, and most importantly, speed was not objectively measured, and all horses were trotted at their preferred speed as in previous studies [12,15,16]. Although horses were trotted at a consistent, handler-controlled pace, velocity differences between conditions were not quantified and may have influenced muscle activation and kinematic variables. Speed represents a significant potential confounder in this study. Rectus abdominis activity has been shown to increase linearly with trotting velocity [1]. Previous pole studies have reported reduced speed over poles [22,31]. If speed was reduced in the pole conditions, alterations in muscle activity and lumbosacral kinematics may partly reflect velocity-related adaptations rather than a direct mechanical effect of poles. As speed was not objectively measured, its contribution cannot be excluded. Future studies should incorporate velocity tracking to distinguish between speed-dependent and intervention-dependent effects.

Surface EMG is inherently limited by susceptibility to crosstalk from adjacent musculature, particularly in regions with overlapping muscle bellies, which is not the case in the muscles included in this study. However, the recorded signals may still not exclusively represent rectus abdominis or longissimus dorsi activity. Furthermore, unilateral electrode placement does not account for potential asymmetry or lateral dominance. In an ideal scenario, measurements should have been taken from both sides simultaneously to understand the effects of laterality. Given previously reported side-to-side variability in equine trunk muscles [30], bilateral recordings would have strengthened interpretation.

Another limitation was the use of two-dimensional kinematics. Two-dimensional kinematic analysis restricts assessment to sagittal-plane motion and does not capture transverse- or frontal-plane spinal dynamics. The equine lumbosacral region exhibits complex three-dimensional motion, including axial rotation and lateral bending. Therefore, subtle multi-planar adaptations to pole exercise or taping may not have been detected. Three-dimensional motion capture would provide a more comprehensive assessment of spinal biomechanics. Furthermore, potential marker displacement may have limited the reliability of the captured data.

Although the evidence on the lasting KT effect is controversial [16,42,43], it may have impacted the data collected after KT conditions. As opposed to other KT research [15], data for all conditions in our study were collected within one day. Due to the lengthy data collection, the positive effect of warm-up and fatigue on locomotor parameters must also be considered [44]. Even with a small adjustment allowance, fixed pole spacing may not account for individual horse stride length, thus reducing protraction/retraction [40], as well as reducing applicability to ridden trot [31].

Lastly, surface electromyography (sEMG) also presents several inherent limitations that should be acknowledged when interpreting these findings. sEMG signals can be influenced by factors unrelated to neuromuscular activation, including subcutaneous adipose tissue thickness, skin impedance, and electrode placement variability. Although efforts were made to standardize the study population, individual differences in fitness level, muscle fiber composition, and body condition score (BCS) were not objectively quantified and may have affected signal amplitude and muscle recruitment patterns. These factors are well recognized in both equine and human sEMG research and can contribute to inter-individual variability, potentially masking subtle intervention effects. Consequently, the recorded activity should be interpreted as an indirect estimate of muscle function rather than a definitive measure of muscle force or activation.

5. Conclusion

Ground poles were associated with increased peak rectus abdominis activity and reduced lumbosacral angle at specific stride phases. These findings suggest a potential role for pole exercise in influencing trunk muscle activation and lumbosacral kinematics, although effects were phase-specific and modest in magnitude. This could create recommendations that poles should be used in conditioning and rehabilitation programs for core strengthening and lumbosacral motion maintenance. However, pole spacing must be carefully considered regarding the purpose of rehabilitation, as LS extension and hindlimb protraction are affected. Kinesiotaping did not independently alter muscle activity or most kinematic variables. Any potential additive effect when combined with poles remains speculative and requires confirmation in larger, controlled studies. Therefore, there is a need for more research on this method and its longitudinal effects to understand the mechanism and tailor rehabilitation to individual horses in the most efficient way.

Authors' Contributions

A.S.: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Writing – original draft; H.J.: Methodology, Project administration, Supervision, Writing – review & editing; R.B.: Conceptualization, Methodology, Resources, Software, Writing – original draft, Writing – review & editing.

Data Availability

The data that support the findings of this study are available from a public repository at: <https://data.mendeley.com/datasets/yv2yyb9xc8/1>.

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Conflicts of Interest

The authors have no relevant financial or non-financial interests to disclose. This research has been presented as a conference abstract at the Alltech-Hartpury Student Conference 2023 (A.S.; H.J.) and IAVRPT Conference 2024 (A.S.; H.J.; R.B.).

Ethical Approval

The current study was approved by the Ethical Committee at Writtle University College (number: 98379136/2023). The study was carried out in accordance with guidance on the operation of the Animals (Scientific Procedures) Act 1986 and associated guidelines. The welfare of all animals was monitored according to a strict protocol, and any distress or decline in condition would result in exclusion from the experiment and appropriate veterinary attention. Fresh water for horses was provided throughout the data collection.

Consent to Participate

Written informed consent was obtained from all owners of horses participating in the study.

Declaration of Generative AI and AI-Assisted Technologies

The authors confirm that no Generative AI or AI-assisted technologies were used in the writing, editing, or preparation of this manuscript. The entire content was authored solely by the individuals listed.

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What Is Understood About the Welfare of Horses Working in Australian Cattle Feedlots: An Introductory Survey

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Abstract

Ridden horses are commonly used to manage cattle in feedlots in a range of countries, including Australia. While there is public concern about the welfare of cattle in feedlots, research into feedlot working horses and their welfare is lacking to date. Accordingly, an online survey was initially developed to ascertain the views of Australian animal and equine communities concerning this cohort of horses and the work they perform. In addition, respondents were asked about their views on animal welfare in general. The survey comprised a mixture of Likert scale questions consisting of six options, multiple-choice responses, and open-ended responses, and was completed by a total of 440 participants. The majority of participants were involved in the equine industry (95.87%), and therefore the findings reflect an equine industry viewpoint. Animal welfare in general was considered to be at a minimum important ($\chi^2 = 20.1$, $df = 5$, $P = 0.001$), and animal well-being was considered extremely important ($\chi^2 = 10.59$, $df = 4$, $P = 0.032$). Animal agency was considered important or very important by a majority (354) of participants ($\chi^2 = 10.6$, $df = 5$, $P = 0.06$). Participants strongly agreed that cattle welfare has the potential to be improved by the use of horses on feedlots ($\chi^2 = 6.17$, $df = 2$, $P = 0.046$). Participants clearly believe that animal and horse welfare is important both generally and in the feedlot industry. This aligns with wider community concerns about the welfare of animals used for, and in association with, food production.

Keywords

Working horse; management; well-being; industry perception; agency

1. Introduction

There is ongoing community concern about the treatment of animals used for food production, including the welfare of cattle housed in feedlots [1]. However, what is less commonly known is that horses are widely used to manage cattle in feedlots in many countries, including the United States of America and Australia. In feedlot work, horses are used by 'pen riders' to assist with the monitoring and assessment of cattle health/welfare, as well as to move cattle around the feedlot. The working conditions of these horses may include long periods of ridden work spanning a full day in varying weather conditions such as heat, rain, and cold, with minimal access to rest or feed during work. In comparison

to other types of working horses such as police [2], riding school [3], equine-assisted therapy [4], ranch [5], carriage [6], and tourism [7] horses, there are no scientific data on the working lives or welfare of feedlot horses or the impact of the horses on cattle welfare. These horses are also subject to higher workloads compared to most other horses [8]. When not working, feedlot horse time budgets mimic those of semi-feral horses over a 24-hour period [8]. Since feedlot working horses often spend more time working and less time being able to perform natural behaviors, the investigation of their welfare during both working and rest periods is of major importance, as only with increased knowledge can their welfare be assessed/managed, and if necessary,

improved. This knowledge is also fundamental in maintaining a social license to operate for working horses in general, as community opinion may disapprove of the use of working horses with limited agency if their welfare is not provided for and information is not readily and publicly available.

In the Australian feedlot industry, horses used for feedlot work are generally owned by their rider (feedlot employee) rather than the feedlot and are considered an essential tool in the work of managing feedlot cattle. In addition, the use of horses in this system means that the wider equine industry can be viewed as a stakeholder in the feedlot industry. This horse-human working relationship, where not only are the horses ridden by humans for work, but they are also owned by them, poses some distinct barriers to welfare, such as individual horse welfare being in competition with the needs of the rider/owner and industry [9,10]. Not only does this horse-human working relationship give rise to questions about how this relationship affects equine welfare, but it may also mean that the equine industry is held by the general public to a higher standard, as more often than not, having horses is seen as a luxury and not a necessity, and horses are often viewed in a similar light to companion species (e.g., dogs) rather than as production animals [11].

The welfare of working horses around the world is the subject of increasing scrutiny [7,12], and it is likely that Australian working horses will, at some stage, also be subject to this scrutiny in common with other Australian livestock industries, such as the Australian dairy industry and the Australian live export industry [13]. This scrutiny will likely be due to two factors: first, the role of a working horse in an already scrutinized livestock production industry and second, the general public's scrutiny of the Australian equine industry as a whole, as already evident in the pressures on public-facing sectors such as racing [13–15].

These public concerns about topics such as animal welfare can lead to pressure on an industry's social license to operate (SLO). The SLO refers to the social or public acceptance of an industry, despite the harms it may cause to the environment, people, or animals, because overall, the industry is believed to benefit society as a whole [14]. Public approval for these types of activities can only be maintained if the particular industry is considered legitimate, consent from industry and community stakeholders is gained, and there is trust between the industry and the wider community in which it operates [16]. Public acceptance is supported by the application and presentation of scientific research that addresses the gaps in industry, but also the perceived gaps that come to light when SLO is addressed [17].

In the case of the use of animals for food production, protection of the welfare of those animals is critical in the maintenance of SLO, and there is extensive literature on the welfare of production animals, including feedlot cattle [1]. Important in the protection of production animals is the assessment of welfare, which has undergone considerable development, from the Five Freedoms [18] to the Five Domains Model [10], which, unlike the former, flexibly incorporates ongoing developments in modern animal welfare science, including animal behavior, animal affective state, and individual animal mental well-being. The Five Domains Model provides a comprehensive, animal-focused framework for

animal welfare assessment. However, as is common in the interaction between welfare assessment and the practicalities of animal production systems, how assessment findings are implemented may not align with current science or community expectations [19]. This tension is likely to be evidenced in the case of feedlot horses on whose work their riders rely to earn an income, but whose working conditions and the operational characteristics of the feedlot environment may not align with or enable changes to improve their welfare. Gaps between best practices, informed by science, and the realities of industry practices may undermine the feedlot and associated equine industries' SLO [13].

The feedlot industry's SLO is not solely based on evidence generated by scientific enquiry but also encompasses the ethical and moral concerns a community may hold [11]. Within the community, the concerns that individual stakeholder groups (e.g., animal and equine communities) may hold about the feedlot industry and the use of horses in that industry, as well as the importance they attach to the various welfare domains, are a valuable subject for research. This is due to the fact that these stakeholder groups may hold either specialized knowledge about the industry or, as a result of their being directly involved in the industry as horse owners, for example, their views may in fact diverge from the general public, as identified in a range of recent public surveys [20,21]. Understanding how welfare and well-being are understood by this cohort of industry stakeholders is crucial due to the lack of definitions and often negative connotations the word welfare holds [22]. This increased understanding will help facilitate future research and welfare improvements that address industry concerns, public concerns, and knowledge gaps [23]. As such, an online survey was initially developed to identify industry stakeholders' (animal and equine community members) understanding/knowledge of animal welfare and the role of horses in Australian cattle feedlots.

2. Material and Methods

An online survey was constructed to gauge industry perceptions about the understanding of animal welfare, equine welfare in general, and the welfare of horses working in feedlots in particular. While the initial survey was aimed at the broader community and industries, after analysis, the focus was changed to the equine community due to the participant industry demographics. The survey was designed with questions specifically relating to feedlot working horses. It also asked participants to rate their general opinion of animal welfare-based words, where these words were based on the Five Domains Model framework [10], but by design the framework was not mentioned to participants.

The survey was created using Survey Monkey (Survey Monkey®, San Mateo, CA, USA) with five iterations. The final version was released after pilot testing with five experienced industry participants. It comprised a mixture of 20 open and closed questions, where skip logic was used to ensure only relevant questions were asked. Participants were recruited via Facebook® and internal university email distribution lists aimed at the School of Agricultural, Environmental and Veterinary Sciences (Charles Sturt University) employees (including academics, professional/technical staff, and students), as they were thought to be representative of the

animal and equine industry/community. The survey was also distributed by individuals through online platforms (e.g., Facebook®).

The term animal community refers broadly to anyone involved with animals, encompassing all individuals and groups, including those engaged with livestock, companion animals, and other species. This includes, but is not limited to, stakeholders such as animal owners, caretakers, industry professionals, policymakers, and welfare advocates. The term equine community broadly refers to anyone involved with horses, whether on an individual or group level. This includes, but is not limited to, stakeholders such as horse owners, caretakers, industry professionals, policymakers, and welfare advocates. To be eligible, participants had to be an Australian permanent resident or citizen over the age of 18 years. The survey was available between August 2021 and December 2021.

The survey comprised a mixture of Likert scale questions consisting of six options: 1. Not at all important, 2. Somewhat important, 3. Important, 4. Very important, 5. Extremely important, and 6. Don't know/unsure; multiple-choice responses for demographic information where participants could choose from predefined response categories with a selected number of options (such as age range or gender), and open-ended responses where participants could provide free-text answers with no restrictions (see **Supplementary Materials**).

2.1. Data Analysis

Survey data were downloaded from Survey Monkey (Survey Monkey®, San Mateo, CA, USA) and imported into Microsoft Excel (Microsoft Office 365). Once imported into Excel, these were saved as a CSV file and imported into JASP STATS 0.15 Version (Amsterdam, Netherlands). Descriptive data analysis was conducted to determine frequencies and percentages of participant demographic data before conducting a series of Chi-squared tests of association (goodness of fit) to investigate the significance of relationships between quantitative responses. Analyses were performed in relation to participant roles in the equine industry (whether they were involved in the industry or not) and their understanding and perception of animal/equine/feedlot working horses' welfare. A probability of $P < 0.05$ was used for significance. Qualitative content provided in open-text responses was manually collated into an Excel spreadsheet in preparation for analysis. Thematic analysis of the free-text responses to open questions was conducted using tags (open codes) to create topics (focused codes), resulting in a number of emerging themes [24].

3. Results

The online survey was completed by 492 participants. Of these, 17 were not over the age of 18 years, two did not reside in Australia, and one participant met both exclusion criteria, so these participants were excluded, resulting in 472 usable surveys. Of these participants, 440 (93.2%) completed the survey fully; however, $n = 52$ did not answer all the questions, with questions being skipped randomly. This resulted in differing numbers of people answering all survey questions, but due to the exploratory nature of the study, all answers were retained. As 492 participants began the survey, there was a

margin of error of $\pm 4\%$ at a 95% confidence interval, based on an estimated Australian equine industry community of 400,000 horse owners [1]. Most survey participants were female ($n = 410$), with a wide range of ages represented: 18–25 years ($n = 128$), 26–33 ($n = 94$), 34–41 ($n = 67$), 42–49 ($n = 52$), 50–57 ($n = 54$), 58–65 ($n = 34$), and over 65 ($n = 11$). Inspection of postcodes provided by 433 participants showed that 282 out of 3333 Australian postcodes were represented, with a prevalence ($n = 51$; 11.8%) in the rural city of Wagga Wagga, Australia (2650), and its surrounding suburbs. Classification of survey participants according to their involvement in the equine industry, that is, whether they worked in the equine industry, just owned horses, or were involved with horses in another capacity, revealed that 95.87% of participants were involved with horses in some form ($n = 418/436$). Just under half of participants (46.5%; $n = 200/430$) worked in the animal production and livestock industry. Only 22.14% ($n = 93/327$) of participants reported having specifically worked in an animal feedlot setting (not restricted to cattle, i.e., sheep). Only 4.2% ($n = 20/472$) of survey participants were not involved in the equine industry, and therefore these responses were excluded from further analysis.

3.1. Equine Industry Participant Perception of Animal Welfare

The majority of participants ($n = 376/379$) who were involved in the equine industry considered animal welfare to be at a minimum important ($\chi^2 = 20.1$, $df = 5$, $P = 0.001$; 373/376), with only 3/379 being unsure or seeing it as not important. The consensus from participants was that animal welfare was at a minimum important ($n = 21$), with the majority ($n = 51$) believing it was either very important or extremely important ($n = 296$).

Animal well-being was regarded as extremely important ($\chi^2 = 10.59$, $df = 4$, $P = 0.032$; 294/378), with none of the participants being unsure if well-being was regarded as important or not important. Animal emotion was seen as either being very important or extremely important ($\chi^2 = 14.59$, $df = 5$, $P = 0.012$; 280/378). Similarly, participants identified animal mental health as very important or extremely important ($\chi^2 = 20.00$, $df = 5$, $P = 0.001$; 311/379).

While there was acknowledgment of the importance of an animal's ability to engage in natural behavior, be provided with an appropriate environment, have good physical health, and receive appropriate nutrition by equine industry participants, these were not significant ($\chi^2 = 6.9$, $df = 4$, $P = 0.144$; $\chi^2 = 6.7$, $df = 5$, $P = 0.242$; $\chi^2 = 3.9$, $df = 3$, $P = 0.276$; $\chi^2 = 0.5$, $df = 3$, $P = 0.922$, respectively). However, participants agreed that all of these factors were either important or very important in relation to animal welfare. Although 354 of the 379 equine industry participants considered animal agency important or to be very important ($\chi^2 = 10.6$, $df = 5$, $P = 0.06$), 7 participants were unsure, and 18 participants deemed it not important.

3.2. Equine Industry Knowledge of Horses on Cattle Feedlots

Participants involved in the equine industry were aware that horses are used on cattle feedlots ($\chi^2 = 46.84$, $df = 1$, $P < 0.001$). Furthermore, they strongly agreed that cattle welfare has the potential to be improved by the use of horses on feedlots ($\chi^2 = 6.17$, $df = 2$, $P = 0.046$). Survey participants were invited

to comment on the use of horses in cattle feedlots and horse well-being. Comments provided were screened, with $n = 27$ removed due to not being related to the use of horses in a cattle feedlot. The remaining responses ($n = 85$) were subject to thematic analysis, yielding four main themes. These themes were: 1. positive horse welfare on feedlots, 2. negative horse welfare on feedlots, 3. positive impacts on cattle welfare using horses on feedlots, and 4. the Five Domains (Figure 1). Although the Five Domains were not explicitly mentioned in any open-ended responses, these responses were classified under the theme of the Five Domains as they aligned with literature on animal welfare, well-being, and the individual domains.

4. Discussion

Current literature on horses, especially that of performance horses [9,10], clearly demonstrates the increasing value being placed on equine well-being and welfare by the equine industry, likely due to increased general public interest in current practices [15,25,26]. This increased interest has led to greater exposure to the outcomes of horses being subject to practices that, although traditional, may not prioritize horse welfare. The increasing application of the Five Domains Model framework to assess horse welfare in a wide range of common, publicly visible equestrian contexts (or scenarios) has highlighted deficits in equestrian practice and how horses are treated, which has threatened the equine industry's SLO [27]. Although the group of horses under examination in this study are arguably part of the livestock production industry, they represent a category of horses who may escape regular public scrutiny due to not undertaking their work in public settings [7,12,28]. These horses are also often subject to more intense workloads than their counterparts, where the lack of

data and current knowledge may impact their welfare in the nonworking hours as well as the working hours.

The term animal well-being is becoming a common expression for lay people to use in place of welfare due to the less negative connotations it appears to hold with the general public [29]. Although there is no commonly accepted definition of either welfare or well-being, the distinction placed on these two words by the public is also evident in the equine industry, because animal well-being was perceived as being more important by participants when compared with animal welfare. This highlights the fact that the framing of situations matters, which is evident in industry but also in how industry is viewed through SLO by the public [30]. It also highlights how framing and knowledge are important.

In this study, although participants were not made aware of or asked about their knowledge of the Five Domains Model specifically, the survey was designed so that the welfare terms participants were asked to rate were modeled on the Five Domains. This was done in an attempt to gauge participant understanding without altering judgments [31]. A 2021 study of United Kingdom horse owner perceptions of welfare found that 60% of the study participants were unaware of the Five Domains Model before they participated in the study [32]. However, after being made aware of the model, participants' opinions in a second survey were significantly impacted, as was how they viewed several of the domains. Once being made aware of the domains, equine emotional state was rated as of higher importance, while behavior, human interaction, and health were then rated as of lower importance. However, views on both the environment and nutrition domains were not impacted by increased awareness of the Five Domains Model [32].

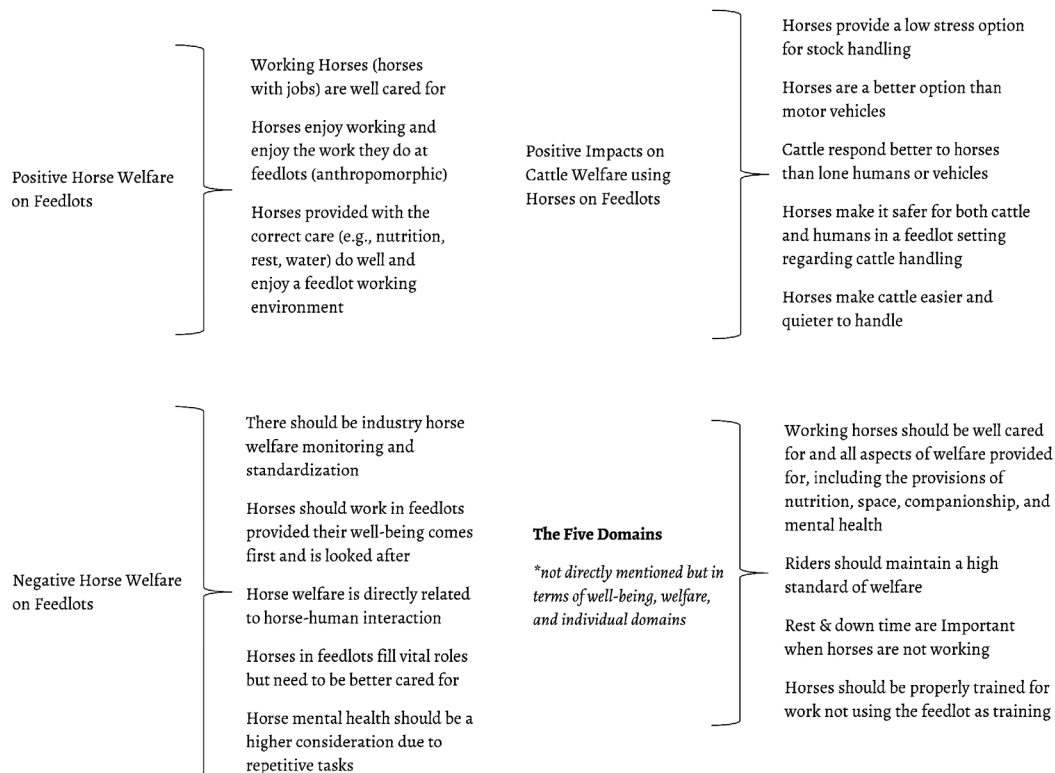


Figure 1: Thematic analysis identified four key themes about cattle feedlot horse welfare from an open-ended survey question.

While survey participants in this study may not have been specifically aware of the Five Domains Model, each domain was clearly seen as important and rated highly in terms of equine welfare, meaning participants thought that each domain or domain-related word was important for horse welfare and animal welfare. The overall importance placed on all welfare words was unanticipated for the equine community. Although the equine community is slowly working toward positive welfare changes, the community can be slow to implement these changes due to cultural norms and a lack of scientific understanding [33–35]. Although the Australian equine community acknowledges the importance of horse welfare and the factors involved in providing good welfare, there is often a stark contrast between the conceptualization of welfare for horses and real-life implemented practices [29,33].

Unsurprisingly, as this study was about horses, it attracted a high number of equine industry participants compared to those working in the general animal industry, meaning there was an increased possibility of bias due to the survey reflecting an equine industry viewpoint. This may mean that industry cannot see the current issues as they are too close to the situation and the situation is filtered through personal experiences and preferences [36]. This situational filter may lead animal owners (in this case equine) to rate their animals' welfare more highly than they do other animals' welfare in similar situations [36,37], and the possibility of emotional well-being of an animal being perceived as greater (happier) than it really is [9,36]. Participants for this survey may have also introduced self-selection bias through the voluntary nature of participation and the dissemination techniques through the university email system, where participants are more likely to respond to surveys that they have experience with or interest in [38]. This limitation, and therefore the subsequent research focus on the equine industry and its views on feedlot working horses, means that although this survey provides information on an unstudied population, the results themselves only provide a point-in-time snapshot for this specific focus group. However, the broader focus of the open-ended questions opens new avenues of research inquiry, as they give insight into how this specific group of participants felt about these horses. While these results cannot be extrapolated in a wider context, they can be used to inform and create more specific future research questions.

The open-ended responses provided in this survey highlighted a generally held view that if feedlot horses are well cared for in all Five Domains, then the horses would thrive, enjoy, and be 'happy' to work in a feedlot environment. Participants stated, "The majority of these horses love what they do and are happy to do it," and "no problem with horses being used in feed lots with cattle as long as their needs are met." In 2004, the Fédération Équestre Internationale (FEI), which governs international equestrian sports, introduced the concept of the 'happy athlete' to the equine industry competition scene [39]. Although this concept was believed to support the improvement of equine performance and welfare by its proposers through improving equine emotional well-being, it does not outline any specific attributes of a 'happy athlete.' Consequently, the term has no clear definition and is therefore open to interpretation. From a

scientific point of view, while this open interpretation may be useful in terms of considering a range of understandings, it can lead to confusion and result in the term acquiring several different meanings depending on what is being discussed and who is discussing it [40]. With no clear definition, the assessment of whether a horse is indeed a 'happy athlete' becomes more complex, as positive affective states remain undeniably difficult to identify and assess, especially when compared with their negative counterparts. This is due to negative states likely being easier to observe, but also being characterized by having a greater range of behaviors [41]. This industry view, i.e., that horses enjoy their job and are 'happy' to work, may lead to riders attributing a greater range of emotional states and experiences to their equine companion than the animal is capable of [42]. Horses, like other animals, possess a complex range of emotions and affective states and associated behavioral responses based on natural motivations which may be different from those of humans [43,44]. While humans may perceive the horse as being 'happy' to perform a certain task, the horse may simply be completing the task as it understands, following trained cues given by the rider, rather than consciously working with the rider to complete the task as a team [9]. Contemporary animal welfare scientists argue that anthropomorphic explanations of animal behavior are unsuitable, particularly during human-animal interactions [45]. However, the opinions expressed in this survey reveal that anthropomorphic beliefs are still widely held and that there is still work to be done to modify them [25,45].

The majority of participants were aware that horses work in Australian feedlots. This may well be due to the Australian affinity with working horses on farms being part of Australian heritage/folklore [46]. In terms of Australian feedlot horses and the work they undertake, no research had been conducted prior to the research presented in this study. In addition to the lack of scientific welfare assessment of horses working in feedlots, industry standards and codes of practice to safeguard these horses' welfare are limited. While the Australian Meat and Livestock Association manual on beef cattle feedlot design and construction provides a comprehensive list for keeping horses and provisions for them on a feedlot site [47], its use is not regulated, and, as a code of practice, compliance with its codes is not mandatory. This means that horse care standards may not only vary between feedlots but also within a single feedlot, as ultimately it is the riders/owners who are responsible for the horse's care. Despite this lack of enforceable legislation, several survey participants in the open-ended responses believed that as long as a horse's needs are met, which includes nutrition, rest, water, and adequate training, then most feedlot working horses will have positive welfare. Participants also thought that not only do the horses experience positive welfare, but their use in feedlots directly impacts cattle welfare, with their use improving cattle welfare.

An animal's previous experiences of being handled will influence its future reactions to handling, i.e., if previously having had a negative experience due to being roughly handled, the animal may be fearful, aggressive, or flighty [48]. Thematic analysis of open-ended responses showed that some participants believed that handling cattle with horses led to the cattle becoming calmer, therefore improving the

safety of the staff handling the cattle. Participants stated, "horses are far more beneficial when working cattle than bikes," and that "working cattle with horses, the cattle are calmer and are easier to educate and handle." However, despite this belief being expressed by survey participants, it is only based on anecdotal evidence, with limited research to support the claim [49]. If the use of horses to manage cattle in feedlots could be found to lead to calmer cattle, this may lead to improvements in cattle welfare if horses were introduced to feedlots in which they are not currently used. However, calmer cattle could simply be a product of calmer handlers who feel safer and less overworked on horseback, or the horse-human relationship may be beneficial to the human-cattle relationship.

5. Conclusion

This study on Australian cattle feedlot horses found that study participants believe the use of horses on a cattle feedlot to be positive for both horses and cattle, provided that the horses' needs are met in terms of the Five Domains Model framework. More research on the Australian feedlot working horse is needed so that the industry does not come under threat of losing its SLO while increasing working horse welfare and perhaps, in doing so, also increasing cattle welfare and the production outputs from a positive horse-human-cattle relationship. While this study is limited by possible self-selection bias of participants and only providing participants' viewpoints in a single timeframe, the results will help build and improve future studies. Future studies could focus on professionals directly involved in feedlots or the horses themselves.

Supplementary Materials

Supplementary Materials contain all survey questions, answers, and skip logic where it applies.

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Authors' Contributions

K.L.: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Visualization, Writing – original draft, Writing – review & editing. C.H.: Visualization, Writing – original draft, Writing – review & editing. H.R.: Conceptualization, Formal analysis, Methodology, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

Data Availability

The data supporting the findings of this study are available on request from the corresponding author.

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Conflicts of Interest

The authors declare that they have no known conflicts of interest that could have appeared to influence the work reported in this paper. All co-authors have seen and agree with the contents of the manuscript, and there are no conflicts of interest to report.

Ethical Approval

The survey was approved by Charles Sturt University Human Ethics Committee Approval Authority H20204.

Consent to Participate

Participant consent was gained as part of the survey (see **Supplementary Materials**), and all data were collected anonymously.

Declaration of Generative AI and AI-Assisted Technologies

The authors did not use any artificial intelligence-assisted technologies in the writing process.

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What Is Welfare? A Qualitative Study into Perceptions of Equine Welfare of Horse Owners

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Abstract

While existing literature broadly addresses equine welfare, limited research has explored horse owners' perspectives on welfare within the contexts of ownership. This study aimed to identify aspects of care and practice that horse owners consider essential for safeguarding equine welfare. An online survey comprising eight open-ended questions was analyzed using reflexive thematic analysis. A total of 341 responses identified four higher-order themes: Equine Husbandry, Human–Horse Interaction, Equitation and Training, and Personal Development and Ethics. Equine Husbandry was the most frequently referenced theme, with respondents emphasizing the importance of appropriate housing and management practices, particularly the provision of year-round turnout, as central to equine welfare. Within the theme of Human–Horse Interaction, owners highlighted the need to understand equine behavior, recognize signs of stress, and treat horses as sentient beings deserving of respect, while avoiding anthropomorphism. The Equitation and Training theme underscored the importance of ethical, evidence-based training practices, including the correct use of tack and equipment. Many respondents expressed negative views toward the use of whips and spurs and stressed the value of qualified coaches who prioritize welfare-focused training. However, concerns were raised about entrenched or outdated coaching practices that may compromise welfare. Participants emphasized the importance of ongoing education, reflection, and a multidisciplinary approach to equine management, including collaboration with veterinarians, professional farriers, and saddle fitters. Despite widespread awareness of welfare considerations, findings suggest the persistence of a knowledge–practice gap. Focusing on education and evidence-based training is recommended to enhance the application of welfare principles in horse ownership.

Keywords

Equine welfare; equine husbandry; human–horse interaction; equitation

1. Introduction

Equine welfare has become a subject of heightened concern in recent years, particularly following several high-profile instances of mismanagement and abuse that have sparked public attention and debate [1]. Horses hold multifaceted importance in modern society, engaging in recreation, elite

competition, breeding, training, sport, coaching, and therapeutic contexts. Consequently, safeguarding equine welfare is not merely a matter of animal care but a prerequisite for maintaining equestrianism's "social license to operate," an informal yet essential societal contract that underpins public acceptance of equestrian practices [2].

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Central to equine welfare is the role of horse owners, whose husbandry, management, and training choices directly impact both the physical and psychological well-being of their horses. However, if not managed or monitored well, seemingly routine practices, such as stabling [3], high-concentrate feeding, or limited turnout, can inadvertently compromise welfare, evidenced by increased stereotypic behaviors [4] and elevated risks of conditions like colic [5].

While equine welfare has traditionally centered on physical health indicators such as body condition, lameness, and disease prevention, contemporary frameworks increasingly recognize the importance of psychological well-being. The Five Domains Model [6] has been instrumental in advancing this shift, highlighting that true welfare encompasses not only the absence of suffering but also the presence of positive affective states such as comfort, pleasure, and agency. In parallel, the field of Equitation Science has emerged as a multidisciplinary area of research that applies principles of learning theory, ethology, and animal welfare science to horse training and management [7]. By focusing on how horses perceive and respond to human interactions, equitation science bridges the gap between performance and welfare, advocating for evidence-based practices that minimize confusion, fear, and conflict behaviors. This growing field offers scientifically grounded alternatives that prioritize both ethical training and the horse's cognitive and emotional needs.

Despite a growing body of research into assessing equine welfare, research into stakeholder perceptions of equine welfare has been limited until recently [8]. Wolframm et al. [9] sought to address this gap with an online survey that garnered 875 responses from Dutch equine enthusiasts, which included horse owners, riders, and drivers. Their thematic analysis revealed three dominant dimensions of perceived welfare: Equine Husbandry, with a strong emphasis on the ability for horses to express natural behavior and appropriate feeding; Human–Horse Interaction, highlighting behavior understanding, respectful treatment, and effective communication; and Equitation, encapsulating rider/driver training, knowledge of tack and equipment, and the importance of qualified instructors.

Notably, Equine Husbandry emerged as the most frequently cited category, with 91% of respondents underscoring the importance of natural behavior components such as free movement, social contact, and forage access. This underscores that Dutch horse owners place profound weight on environmental and management practices as foundational to welfare, pointing to a widespread appreciation of horses' intrinsic needs yet a persistent gap between knowledge and implementation [10,11].

By examining how horse owners outside the Netherlands define and prioritize equine welfare across varying contexts and settings, this research intends to expand upon the findings of [9]. The aim of the current study is to deepen the understanding of the gaps between awareness and practice among English-speaking equine owners, to inform the development of tailored educational and policy initiatives that align equine management more closely with authentic welfare standards.

2. Materials and Methods

2.1. Survey Recruitment and Distribution

Following institutional ethical approval (Hartpury University Ethics Committee, ETHICS2023-184) and adhering to the guidelines of the Declaration of Helsinki, individual horse owners aged 18 years or older were targeted. Recruitment took place via Facebook, LinkedIn, and various online equine-related sites. The survey was distributed using MS Forms, an online survey platform. Following an introduction to the aim of the study at the start of the survey, respondents were asked to provide active informed consent to participate. All respondents were assigned unique numerical identifiers to ensure anonymity.

2.2. Survey Design

This survey was adapted from the questionnaire designed by Wolframm et al. [9], which was used to investigate "What is Welfare? A Qualitative Study into Perceptions of Equine Welfare of the Dutch Equestrian Community." The survey was administered in English, available in the United Kingdom and North America, and consisted of three parts with a total of 20 questions (**Supplementary Materials**).

The first part of the survey collected demographic information of respondents (gender, age, education, and type of involvement with horses). In addition to a number of predefined options, participants were also given the option to respond in an open-text format.

Sections 3–7 contained eight open questions concerning equine husbandry, riding, human–horse interaction, welfare, and training practices. To elucidate as much detail as possible regarding which aspects participants found important when it comes to equine welfare while staying as close to reality as possible, the questions were phrased as scenarios, e.g., "A friend wants to stable her horse at a livery/boarding facility with welfare as a top priority. What advice would you give her?" "A close acquaintance's daughter has just started riding. What should she know or be able to do to become a good rider and ensure horse welfare?" "Thinking back to the start of your horse career: what do you wish you had known or been able to do then that you can do or know now?" "What do you think everyone who interacts with horses should know or be able to do?", and "Can we improve the welfare of horses in all areas of their lives? Where should we focus?"

2.3. Data Analysis

Open-ended question responses were analyzed using qualitative thematic analysis, following the method of Graneheim and Lundman [12]. The analysis focused on condensing and interpreting meanings. First, all responses were collated and read in full. Two researchers (S.O. and V.L.) independently reviewed the content to identify key sentences and phrases that conveyed similar meanings, which were subsequently coded. The researchers then met to compare their coding, discuss discrepancies, and reach consensus on the final codes. These codes were organized into lower-order and higher-order themes to reflect their content and were further filtered and grouped into categories to summarize participants' discussions and conclusions.

A meaningful unit was defined as a word, phrase, or sentence that could be attributed to a recognizable theme recurring

across respondents' answers. A single sentence could contain multiple meaningful units, one meaningful unit, or none, depending on how meaning was expressed and how the data were segmented during coding.

3. Results

The survey yielded 341 submitted responses. The highest number of respondents were aged between 55–64 years ($n = 87$; 25.5%), closely followed by those aged 25–34 years ($n = 80$; 23.5%). Most respondents were female ($n = 314$; 92.1%). A total of 32.3% of respondents listed equine-industry professions ($n = 110$). Additionally, 23.5% of respondents were primary-sector equine-industry professionals ($n = 80$). Recreational riders ($n = 88$) and amateur competitors ($n = 86$) represented 51% of the survey population. Almost half of respondents were educated to the bachelor's degree level or above ($n = 169$; 49.5%), with 80.4% having a formal equine education ($n = 274$). Formal equine education was defined as equine-specific certification or instructor-led training from Pony Club to Ph.D. The top three disciplines in which respondents were involved

were Dressage ($n = 168$; 49.3%), Trail Riding/Recreational ($n = 155$; 45.5%), and Jumping ($n = 147$; 43.1%) (note that respondents could select multiple disciplines). The full demographic overview can be found in **Table 1**.

A total of 5,944 meaningful units were identified across all questions. **Table 2** provides an overview of the distribution of meaningful units across each question, illustrating the relative contribution of responses to the overall dataset.

Four higher-order themes were generated: Equine Husbandry, Equitation and Training, Human–Horse Interaction, and Personal Development and Ethics. **Table 3** outlines these higher-order themes alongside their associated lower-order themes and definitions, providing a conceptual framework for the analysis. **Tables 4–7** (thematic results tables) present the frequency and percentage of coded responses within each higher-order theme, offering a descriptive summary of the prominence of specific categories and allowing for comparison across themes.

Table 1: Demographic characteristics of respondents.

Demographic variable and category	n	Percentage (%)
Age		
18–24	30	8.8
25–34	80	23.5
35–44	44	12.9
45–54	60	17.6
55–64	87	25.5
65–74	35	10.3
75 and older	5	1.5
Gender		
Female	314	92.1
Male	18	5.3
Non-binary	6	1.8
Prefer not to say	3	0.9
Primary involvement in the equine industry		
Owner/employee of a direct horse-related business	80	23.5
Owner/employee of horse-related products business	5	1.5
Owner/employee of horse-related services business	25	7.3
Competitive rider at the national or international level	13	3.8
Competitive rider at amateur level	86	25.2
Recreational rider with one or more horses	88	25.8
Owner of unriden horses	28	8.2
No own horse, ride at a riding school	7	2.1
Other	9	2.6
Location		

Demographic variable and category	n	Percentage (%)
Europe	11	3.1
UK and Ireland	316	92.7
USA	7	2.1
South Africa	7	2.1
Highest level of education		
Some secondary or high school	6	1.8
High school diploma, GCSE, CSE	34	10.0
AS or A level, GCE, Matric	34	10.0
Some university or college	34	10.0
College Diploma	27	7.8
Bachelor's degree	109	32.0
Master's degree	50	14.6
Ph.D.	10	2.9
Other	2	0.6
Professional certification	35	10.3
Formal equine education*		
University, higher education	61	17.9
Equine diploma or certificate	78	22.9
Equine veterinary medicine	7	2.1
Full coaching certificate (BHS, UKCC, EQASA)	59	17.3
Rider level program or equine management course	69	20.2
Pony Club	59	17.3
Currently studying	9	2.6
Life experience	10	2.9
None	77	22.6
Other	25	7.3
Years in the horse industry		
0–5	11	3.2
6–10	24	7.0
11–20	92	27.0
21–30	48	14.1
30 or more	166	48.7
Disciplines involved with*		
Dressage	168	49.3
Trail riding/recreational	155	45.5
Jumping	147	43.1
Riding club	67	19.6
Showing	63	18.5
Eventing	45	13.2

Demographic variable and category	n	Percentage (%)
Hunting	42	12.3
Endurance	25	7.3
Western	15	4.4
Driving	13	3.8
Liberty, groundwork, or horsemanship	10	2.9
Polo	10	2.9
Mounted Games	9	2.6
Racing	8	2.3
Vaulting	7	2.1
Rescue, rehoming, and rehabilitation	5	1.5
Equine agility	3	0.9
Coaching	2	0.6
Horseback archery	2	0.6
RDA	2	0.6
Side saddle	2	0.6
TREC	2	0.6
Working Equitation	2	0.6
Other	14	4.1
None	8	2.3

*Some respondents have multiple formal equine qualifications or are involved in multiple disciplines.

Table 2: Answer point analysis across all eight questions.

Question	Total meaningful units
Q1. A friend wants to stable her horse at a livery/boarding facility with welfare as a top priority. What advice would you give her?	1188
Q2. A close acquaintance's daughter has just started riding. What should she know or be able to do to become a good rider and ensure horse welfare?	903
Q3. Thinking back to the start of your horse career, what do you wish you had known or been able to do then that you can do or know now?	519
Q4. Would you do anything differently?	446
Q5. What do you think everyone who interacts with horses should know or be able to do?	692
Q6. Are there any current challenges you face in interacting with horses? Consider things you might be afraid to do or unsure how to approach. Perhaps you sometimes need some support, or you are unsure who to ask.	431
Q7. Do you think traditional horse training methods are appropriate, or are there other techniques that may improve horse welfare?	756
Q8. Can we improve the welfare of horses in all areas of their lives? Where should we focus?	1009
Total	5944

Table 3: Definitions of higher-order and lower-order themes.

Higher-order themes	Lower-order themes	Description
Equine husbandry	Importance of housing and management	Constant access to forage and water, freedom to move, knowledgeable caregivers with an understanding of needs and holistic horse care, and inspecting facilities to ensure needs are met.
	Year-round turnout	Access to turnout all year, with mixed-species forage, compatible friend groups, enough space, and protection from the weather.
Human–horse interaction	Multidisciplinary care (vets, farriers, saddle fitters)	Access to qualified specialists when needed, and appropriate treatment and care
	Understanding horse behavior	Observing horses and understanding what their behavior may mean, and being able to communicate clearly and consistently
	Identifying signs of stress and pain	Being able to identify lame horses and subtle signs of pain, stress, or distress, and modify care or training appropriately
	Treating horses as sentient beings	Having the values that recognize and respect sentience and emotional well-being when dealing with horses.
	Avoiding anthropomorphism	Understanding that horses do not think like people and avoiding ascribing human attributes to behavior or accessorizing that may be detrimental to welfare
Equitation and training	Ethical training principles	Understanding how to train horses ethically, closely linked with human–horse interactions, and protecting welfare and well-being
	Knowledge of tack and equipment	Understanding how tack should fit and the effects of equipment
	Negative views on whips and spurs	Regret overusing artificial aids such as whips and spurs, and the use of equipment to punish rather than reinforce
	Importance of qualified, evidence-based coaches	Finding qualified, evidence-based coaches, questioning practices, and advocating for the horse
	Training of the rider	The importance of posture, seat, balance, and fitness, the use of cues, and human well-being
	Training of the horse	The importance of groundwork, a positive state and/or environment for training, and an understanding of equine learning theory
Personal development and ethics	Impact of coaching philosophies on owner beliefs	Regulated, accredited, insured, and supportive evidence-based coaches, riding schools, and mentors
	Desire for continuous education	Access to resources to learn, and directing of research to improve education and understanding
	Ethical reflection and growth	Learning and improving understanding, regardless of where we started our journey with horses, a sense of responsibility

Table 4: Thematic analysis results for respondents across the higher-order theme of Equine Husbandry.

Lower-order theme	Category	N	%
Importance of housing and management	General horse knowledge, horsemanship skills, and understanding of welfare needs	318	93
	Forage, frequency of feeding, type, and quality of food and water	314	92
	Housing, stable size, bedding, and time stabled	154	45
	Staff and livery yard owner knowledge	88	26
	Consult others/recommendations	84	25
	Free movement	57	17
	Accreditation and licensing of livery yards, owners, and knowledge tests	31	9
	Cleanliness of facilities	29	8

Lower-order theme	Category	N	%
	Importance of human-focused facilities	28	8
	Indiscriminate breeding	16	5
	Enrichment opportunities	14	4
	Cost of livery/boarding	11	3
Year-round turnout	Access to appropriate turnout (grass type and suitability, space)	336	98
	Social contact with other horses	235	69
	Ability to perform natural behaviors	99	29
	Protection from the weather	36	10
Regular access to multidisciplinary care	Veterinary care	64	19
	Others, e.g., physiotherapists	32	9
	Saddle fitters	31	9
	Qualified farriers	23	7

Table 5: Thematic analysis results for respondents across the higher-order theme of Equitation and Training.

Lower-order theme	Category	N	%
Importance of qualified, evidence-based coaches	Access to supportive, experienced, and trustworthy holistic trainers, coaches, mentors, and riding school teachers	341	100
	Importance of regular lessons and formal instruction for novice owners, livery yards, and training establishments	82	24
	Question practices, advocate for the horse, collaborate, and find like-minded people	79	23
	Regulated, accredited, and insured	77	22
Ethical training principles	Ethical, consistent, and welfare-based training	341	100
	Conflicting views on "traditional" vs. "modern" training techniques, both within an individual and viewed in practice	273	80
	Rider knowledge, skill, position, and fitness	264	77
	Importance of correct ground-schooling	98	29
	Equine fit for purpose and understand the horse as an individual	94	28
	Human mental, emotional, and physical well-being and confidence	73	21
	Positive reinforcement training	44	13
	Negative reinforcement training	33	10
	Natural horsemanship	32	9
	Concern about welfare in competition	28	8
Knowledge of tack and equipment	Knowledge of tack and fitting	103	30
	Misuse of training aids and equipment	98	29

Table 6: Thematic analysis results for respondents across the higher-order theme of Human–Horse Interaction.

Lower-order theme	Category	N	%
Understanding horse behavior	Human–horse communication	263	77
	Knowledge of behavior	225	66
	Positive affective state	44	13
	Addressing fear, anxiety, and aggression in horses	12	3
Identifying signs of stress and pain	Recognizing abnormalities	206	60
Treating horses as sentient beings	Patience	79	23
	Autonomy	78	23
	Kindness	66	19
	Respect	59	17
	Partnership	58	17
	Empathy	28	8
	Gentleness	26	8
	Calmness	25	7
	Compassion	19	6
	Trust	19	6
Avoiding anthropomorphism	Recognizing sentience	10	3
	Emotional control, avoid anthropomorphism, manage expectations, and human perception of cruelty	67	20
Safety	Safety of the horse, first aid	67	20
	Safety of the rider, safety on the roads	53	15
	People not adhering to health and safety requirements	11	3

Table 7: Thematic analysis results for respondents across the higher-order theme of Personal Development and Ethics.

Lower-order theme	Descriptive category	N	%
Desire for continuous education and knowledge development	Knowledge, education, research, human behavior change, and decision-making	108	32
	Strengthen equine welfare legislation	25	7
Ethical reflection and growth	Commitment to and responsibility for bettering horse welfare	183	54
	Acceptance of past actions or decisions	110	32
	No current challenges	94	28
	Access to education	91	27
	Personal growth, learning, and reflection on past actions	45	13
	Trust in your instincts and decisions	17	5
	Concern over decision paralysis in welfare matters	10	3

4. Discussion

The current study aimed to investigate the perspectives of equine owners on which aspects contribute to equine welfare. The following discussion focuses on the most salient aspects and what they might mean for the practical application and interpretation of equine welfare.

4.1. Higher-Order Theme Equine Husbandry

Equine Husbandry emerged as the most frequently mentioned theme in this survey, incorporating three lower-order themes: Importance of Housing and Management; Year-Round Turnout; and Multidisciplinary Care. Horse owners considered welfare a multifaceted issue that encompasses

physical health, psychological well-being, and the ability to express natural behaviors. Findings from this study highlight that horse owners acknowledge the critical role that housing and turnout practices play in supporting these welfare domains. Horses are social, grazing, and browsing animals that evolved to move and interact freely within a herd structure [13]. As such, restrictive housing, such as individual stabling for extended periods, can negatively impact their welfare by limiting movement, social contact, and opportunities for natural behavior [3,14]. However, the size and type of stable appear to be important considerations for participants in this study to ensure that the horse's innate needs are met.

Respondents overwhelmingly cited access to turnout as a high priority for equine welfare. Year-round turnout, particularly in social groups and environments that support foraging, has been shown to significantly reduce behavioral signs of stress and frustration, including stereotypies such as weaving and crib-biting [15]. Research also suggests that horses housed in enriched, pasture-based systems display lower cortisol levels and better behavioral indicators of well-being compared to their stabled counterparts [16,17]. Additionally, turnout opportunities promote physical health by supporting musculoskeletal integrity, reducing the risk of colic [18,19], and encouraging healthy gastrointestinal function through natural grazing patterns.

Importantly, year-round turnout supports positive affective states in horses, a key component of modern welfare assessments. According to the Five Domains Model [6], the mental state of the animal is influenced by factors such as nutrition, environment, and behavioral freedom. Environments that allow for consistent turnout, even in colder months, enable horses to engage in species-typical behaviors such as locomotion, social grooming, and exploration. These behaviors not only satisfy behavioral needs but also contribute to emotional well-being, which is now considered crucial to equine welfare.

Furthermore, there is increasing pressure from both within the industry and from animal welfare organizations to move toward housing systems that reflect horses' ethological needs. Research suggests that integrated management systems, those that combine access to shelter, forage, social interaction, and the need for variation in the field, increase opportunities for horses to engage with a more varied and stimulating environment, both at the group and individual levels, and are more sustainable in the long term and foster a healthier, more manageable equine population [3,20,21]. Considering this evidence, promoting year-round turnout within suitable environments should be viewed not as a luxury or seasonal privilege, but as a fundamental aspect of good equine care and welfare.

4.2. Equitation and Training

This study reinforces the critical role that equitation and training practices play in determining equine welfare outcomes. Four lower-order themes emerged: Ethical Training Principles, Importance of Qualified, Evidence-Based Coaches, Knowledge of Tack and Equipment, and Negative Views on Whips and Spurs. These themes reflect a growing recognition that equine welfare is not only shaped

by management practices but also by the methods and mindset employed during training and riding.

The theme of Ethical Training Principles underscores the necessity of training systems that respect the horse's cognitive and physical capabilities. Research findings advocate for training that is consistent, clear, and uses the least aversive methods possible [22]. Horses learn most effectively when cues are applied with appropriate timing and pressure, and when responses are reinforced in a predictable manner. Ethical training reduces conflict behaviors, fear responses, and stress, which are all markers of compromised welfare [7]. Furthermore, training based on learning theory promotes voluntary cooperation rather than submission, helping to preserve the horse's agency and emotional well-being [23].

Participants also highlighted the importance of qualified, evidence-based coaches. Coaching practices that integrate equitation science principles lead to more ethical, effective, and welfare-friendly outcomes. Yet, many coaches still rely on traditional or anecdotal approaches that can perpetuate misunderstandings of equine behavior and learning [8,24,25]. Equestrian coaches often lack consistency in their knowledge of learning theory, which can lead to confusing or even aversive experiences for horses [26–28], suggesting that coaches educated in equitation science or its guiding principles are better equipped to guide riders in using clear signals, avoiding punishment, and recognizing signs of mental or physical discomfort in their horses. This theme also links to improved rider safety and long-term horse soundness, reinforcing that welfare and performance are not mutually exclusive.

Knowledge of tack and equipment emerged as a pivotal concern, particularly in relation to how poorly fitted or misused tack can result in discomfort, injury, or behavioral conflict [29–31]. The FEI emphasizes that all equipment must be functionally appropriate, correctly fitted, and not interfere with the horse's natural biomechanics, but a lack of awareness among horse owners, riders, and coaches about the physiological and psychological impact of equipment represents a significant welfare risk that could be mitigated through formal education and updated industry standards.

Lastly, the negative effects of whips and spurs were a consistent concern among participants. While often considered traditional aids, their improper use contradicts the principles of negative reinforcement and can act as punishment if applied with excessive force or ambiguity [7]. Research has shown that spurs and whips can induce fear, sensitization, and even learned helplessness when used inappropriately [32] and can cause visible injury [33]. The over-reliance on whips, spurs, and other training aids often signals a breakdown in training clarity or rider skill, further highlighting the need for evidence-based coaching and ethical oversight.

This study demonstrates that equine welfare cannot be separated from the processes of training and riding. Evidence-based theory, such as the ISES First Principles, FEI Ethical Training Method, and the International Group for Equestrian Qualifications (IGE) Core Competencies, provides scientifically grounded frameworks for assessing the ethical integrity of training practices and promoting the welfare of horses in equestrian sport and leisure. Integrating

such principles into coaching, rider education, and equestrian culture at large is essential for fostering a more humane and sustainable future for horse–human partnerships.

4.3. Human–Horse Interaction

The findings of this thematic analysis indicate that horse owners' understanding of equine welfare is heavily influenced by the quality of human–horse interaction, reflected through themes such as Understanding Horse Behavior, Identifying Signs of Stress and Pain, Treating Horses as Sentient Beings, and Avoiding Anthropomorphism. Together, these lower-order themes support the higher-order concept that equine welfare is inextricably linked to how humans perceive and interpret horses' needs and behaviors.

Owners who recognized horses as sentient beings were more likely to prioritize welfare needs such as appropriate turnout, social contact, and mental stimulation. Recent cross-cultural research supports this, finding that owners who attributed emotional and cognitive capacities to their horses tended to provide higher welfare standards, including better physical health and more opportunities for natural behaviors [34]. Treating horses as sentient beings aligns with contemporary welfare science, which includes not only the absence of disease or discomfort but also the promotion of positive mental states [6].

The theme Understanding Horse Behavior emerged as foundational to effective welfare practice. Research suggests that equestrians often emphasize physical health and visible indicators over mental and emotional states [35–37]. This narrower, biologically focused view can overlook horses' affective experiences and reflects a fragmented understanding of welfare, which may limit welfare improvements, particularly when behavior is misunderstood or misjudged. Understanding horse behavior was also central to owner perspectives on welfare. Yet, horse owners often prioritize physical indicators of welfare (e.g., body condition) over behavioral ones, sometimes overlooking critical signs of distress [38]. This highlights the need for improved education around ethologically grounded behavioral cues and their links to emotional states. Increased awareness of these cues would allow for earlier intervention and more nuanced care decisions.

Integrating the theme of Avoiding Anthropomorphism provides critical nuance here. While the projection of human emotions onto horses can be misleading, rigid rejection of anthropomorphic thinking can equally fail to acknowledge an animal's inner life [39]. Findings from this study suggest that horse owners advocate for a balanced "critical anthropomorphism," a reflective, scientifically informed empathy that allows humans to interpret horse behavior without projecting unjustified human emotions. This sensitized understanding enables more accurate interpretation of equine behavior while mitigating the risks of misrepresentation [39].

Research emphasizes that welfare outcomes are shaped not just by management practices, but by the human attitudes, skills, and emotional responses behind them [38]. Equine welfare is therefore both a behavioral and relational construct. Owners' beliefs about sentience, emotional capacity, and behavioral interpretation profoundly shape the lived experience of horses. To raise welfare standards, future interventions should aim not only to improve practical

management but also to enhance owner education on equine behavior and emotional needs.

4.4. Personal Development and Ethics

The fourth theme of Personal Development and Ethics captured internalized coaching philosophies, the pursuit of ongoing education, and the capacity for ethical reflection. These findings highlight that equine welfare is not solely determined by technical knowledge or management practices but is deeply affected by the cognitive and moral frameworks through which humans understand their role in the horse–human relationship.

The Impact of Coaching Philosophies on Owner Beliefs emerged as a powerful driver of attitudes and behaviors. Participants frequently described their early equestrian experiences as formative, often adopting their coaches' approaches, whether positive or aversive, without critical evaluation. This aligns with previous research indicating that coach attitudes and methods are among the most influential factors shaping an owner's perception of acceptable training and management practices [16]. Coaching philosophies that prioritize submission, dominance, or "quick fixes" can normalize coercive or aversive techniques, thereby undermining equine welfare, a pattern also evident in non-equestrian sports [40–42]. In contrast, coaches who promote learning theory, combined reinforcement, and emotional awareness in horses are likely to foster more ethical and evidence-based practices among their students, thereby supporting welfare-aware coaching and enhancing motivation and learning, as reflected in non-equestrian coaching methodologies [43–45]. Therefore, the pedagogical stance of equestrian coaches plays a pivotal role in either reinforcing or reshaping welfare-relevant beliefs among horse owners.

A strong Desire for Continuous Education was another recurring theme among participants who demonstrated more welfare-conscious approaches. Owners who actively sought out new scientific knowledge through workshops, academic literature, or evidence-based training systems may be more equipped or willing to question traditional practices and implement humane alternatives. This motivation aligns with the concept of "lifelong learning" as critical to advancing welfare standards in equestrian contexts [3]. Moreover, the increasing availability of accessible equitation science resources is helping to democratize knowledge and support owners in aligning their practices with current welfare frameworks, such as the Five Domains Model [6]. Continuous education also fosters adaptability, allowing owners to respond to new research findings and improve both their horsemanship and ethical decision-making over time, and to utilize ethical frameworks designed to support horses in sport and recreational use [46]. However, these resources need to be accessible to the wider equestrian population, and other studies call for the development of further education materials to support this learning process [8].

The theme of Ethical Reflection and Growth reinforces the view that equine welfare is, in part, a moral endeavor. Participants who described their evolving understanding of the horse's sentience, emotional needs, and learning capacity also reported changes in their practices, often moving away from punitive or ambiguous training methods toward more

transparent and horse-centered approaches. This aligns with research on moral development in animal care, which shows that individuals who engage in reflective thinking about animal welfare are more likely to support autonomy and positive affect in animals under their care [47]. The ISES First Training Principles, the FEI Ethical Training Method, the IGEQ Core Competencies, and other evidence-based training methods provide a valuable framework for promoting interventions that are not only effective but also minimized in terms of aversiveness, aligning with broader animal welfare goals. Encouraging ethical growth in equestrians through qualifications that facilitate reflection, value clarification, and exposure to animal welfare science may therefore be a powerful tool in shifting industry norms.

Taken together, these findings highlight that personal development and ethics are integral components of improving equine welfare. Owner behavior is not static but evolves through exposure to coaching, education, and self-reflection. Programs aimed at welfare enhancement should therefore include not just practical skills but also opportunities for critical engagement with ethical and scientific principles. By embedding personal development into equestrian education, the industry can better support the transition from outdated views of horsemanship toward practices rooted in empathy, evidence, and ethical integrity.

4.5. Limitations

Several potential biases associated with the study's sampling and design should be acknowledged. The sample was predominantly female, which aligns with similar studies on equine welfare [48,49], but may have introduced gender-related bias, as women are generally more engaged in animal welfare issues [50]. As participation was voluntary, there is a risk of self-selection bias, with individuals already interested in equine welfare being more likely to respond. This may have skewed responses toward more welfare-conscious views, as noted in similar research [16]. Social desirability bias may also have influenced responses, leading participants to emphasize welfare-centered approaches or target perceived coercive practices, as ethical horsemanship and athlete welfare are increasingly socially valued in equestrian contexts [51]. Nonetheless, the findings offer valuable insights into prevailing attitudes within an engaged equestrian population.

Open-ended responses may have been influenced by participant characteristics. Scenario phrasing and question order may have introduced framing and primacy effects, with earlier items potentially receiving more attention. Finally, the range of respondent expertise may have affected the consistency of responses. However, given the study's aim to reflect the diversity of equine owners, such variation is seen as a strength rather than a limitation. Interpretation bias is inherent in qualitative research due to the researchers' role in theme development [52]. To minimize this, we adhered to recommended qualitative guidelines, including whole-dataset coding and peer-reviewed analysis.

5. Conclusion

This study offers valuable insights into how members of the wider equestrian community perceive and prioritize equine

welfare. Thematic analysis revealed a strong awareness of welfare as a multifaceted concept, extending beyond basic husbandry to include the quality of human–horse interactions, training methods, and ethical decision-making. While the study did not directly assess participants' knowledge, the frequent reference to key welfare principles suggests a solid foundational understanding among horse owners and enthusiasts. However, the continued presence of welfare concerns within equestrian settings highlights a gap between awareness and consistent application in practice. This underscores the need for further efforts to translate knowledge into meaningful change at the grassroots level. Education and training initiatives tailored to the realities of daily horse care across various disciplines, cultures, and experience levels will be crucial in closing this gap.

Overall, the findings affirm a widespread and genuine concern for horse welfare. The next step lies in empowering individuals through evidence-based guidance and accessible education to embed welfare-focused practices into everyday routines. Strengthening this connection between intention and action is essential for ensuring a more ethical, informed, and sustainable future for horses and the people who care for them.

Supplementary Materials

The **Supplementary Materials** include the original survey questions in English.

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Authors' Contributions

V.L.: Conceptualization, Methodology, Formal analysis, Writing – original draft, Writing – review & editing. S.O.: Formal analysis. C.B.: Conceptualization. G.T.: Writing – review & editing. I.W.: Conceptualization, Methodology, Writing – review & editing. All authors have read and agreed to the published version of the manuscript.

Data Availability

Data storage was conducted according to the Research Data Management policy framework of Hartpury University. Data management adhered to the principles of Open Science, and data are available upon request.

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Conflicts of Interest

The authors declare conflicts of interest.

Ethical Approval

The survey was conducted according to the requirements of the Hartpury University Ethics Committee (Approval No. ETHICS2023-184) and followed the guidelines of the Declaration of Helsinki.

Consent to Participate

Following an introduction to the aim of the study at the start of the survey, respondents were asked to provide active informed consent to participate. All respondents were assigned unique numerical identifiers to ensure anonymity.

Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

During the preparation of this work, the authors used Microsoft Copilot to improve readability. Following the use of this tool, the authors reviewed and edited the content as needed and took full responsibility for the final version of the publication.

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Alignment Between Gait Parameters and Judging of Canter Quality in International Vaulting Horses

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Abstract

Like most aesthetic sports, judging performance in equestrian vaulting is subjective. The complexity of judging often exceeds human cognitive capacities and can give rise to bias. The horse score makes up 25% of the total score, including the general quality of the canter and training level of the horse (A1 score), the execution of the performance and the horse's willingness and behavior (A2 score), and the quality of the lunging. The aim of this study was to compare the 6 scores of A1 (average of rhythm, relaxation, connection, impulsion, straightness, and collection) and the A2 score (vault-ability) from judges with 10 measured locomotor parameters. Thirty-three international-level vaulting horses were equipped with an inertial measurement unit (128 Hz) fixed to the sternum to calculate positions and movements in the sagittal and transverse planes and to calculate a quality index from a Fast Fourier Transform of the dorsoventral accelerometric signal. The head and neck were positioned with side reins, and the horses were filmed under competitive conditions at a left-lead canter from the judge's point of view, outside of the circle. Five international judges scored relaxation, connection, straightness, impulsion, rhythm, collection, and vault-ability from the videos in random order. The relationship between measurements and judges' scores was analyzed with Spearman's correlation ($P < 0.05$), and a Mann–Whitney U test ($P < 0.05$) was performed to distinguish locomotor parameters of horses judged correct and incorrect, distinguished by a k-means method. A horse that had at least one good score received good scores in all evaluated elements, each consistently associated with the same locomotor parameters. The group of correct canters, determined by the judges' scores using the k-means method, was characterized by good elevation (14 ± 1 vs. 13 ± 2 cm; $P = 0.013$), good propulsion (6.7 ± 1.4 vs. 5.7 ± 1.7 m/s²; $P = 0.005$), and good regularity of the three beats (0.016 ± 0.004 vs. 0.019 ± 0.004 m/s³; $P = 0.018$). Horses were slightly inclined to the inside of the circle and balanced on their hindlimbs. These measures can guide judge training and scoring system improvements.

Keywords

Judge; score; kinematic; locomotion; circle; lunger

1. Introduction

Vaulting is one of the seven equestrian disciplines recognized by the Fédération Équestre Internationale (FEI). This discipline consists of gymnastic elements performed on a horse at a canter. During a FEI Vaulting Competition, one judge evaluates the horse's performance (Judge A), including

the general quality of the gait and training level of the horse (A1, 60%), the vault-ability (A2, 25%), as well as the quality of the lunging (A3, 15%). The total horse score accounts for 25% of the final score of the test [1].

The canter is an asymmetric gait with synchronization of the movements of the diagonal pair of limbs separated by

a suspension phase [2]. A correct canter has a well-defined beat with a clear moment of suspension. On a circular line, centripetal forces affect the horse, and the horse will lean toward the inside of the circle (inclination). The hooves push outward against the ground, and the resultant force moves toward the inside. It is mainly the front limbs that do this work, while the forces of the hind limbs provide propulsion [3]. It is expected that the horse shows a degree of collection to carry the vaulter.

Faults are sometimes difficult to identify with the naked eye. Judging aesthetic disciplines is a very complex task, which can exceed human cognitive capacities [4]. Over the past few years, there has been an increasing number of scientific studies investigating sports refereeing. Studies have looked at objective measures of horses' performance [5], but less frequently at the quality of the canter, and, as far as we know, none have studied the quality of the canter on a circle. A few studies have investigated the link between the kinematic performance of the horse and the judges' scores [6,7]. These studies reveal that the most useful predictors of equestrian performance are asymmetry of trunk movements for dressage and the distance of landing, elevation of the body, and lifting of the front limbs for jumping performance. No similar study has been conducted for the discipline of vaulting. This would make it possible to identify one or more indicators of canter quality in order to better judge it and improve training. Consequently, it would be interesting to identify any correlations between kinematic measurements of the vaulting horse and judges' scores.

The aim of this study was to identify objective indicators to help judge canter quality. We hypothesized that propulsion, balance, and inclination are indicators of vaulting canter quality. To this end, 33 international-level vaulting horses were evaluated by five international judges under similar conditions to those of a competition. The horse cantered on a constant circle with a minimum diameter of 16 m and was equipped with side reins, with or without an elastic insert, fixed to a surcingle. The vaulter performed a series of compulsory exercises. The judges' scores were compared with measured locomotor parameters of canter obtained from an inertial measuring unit (IMU) fixed to the horse's sternum. This comparison enabled us to analyze and discuss the current scoring system.

2. Materials and Methods

2.1. Animals

A total of 33 high-level vaulting horses (13 ± 4 years of age with 4 ± 3 years of international experience) were included in the present study. All horses had previously competed at the international level. There were 29 geldings, two mares, and two stallions. They were lunged by 19 lungers familiar to the horses, with 9 ± 4 years of international experience. Participants were recruited on a voluntary basis following a presentation of the project at an FEI vaulting seminar. All participants signed an informed consent form beforehand.

2.2. Study Design

The study was carried out between December 2021 and February 2023 as a multicenter study at six different test centers in four countries (France, the Netherlands, Denmark,

and Finland). The test area was a 22-m circle enclosed by a low fence or other suitable material, with the lunger in the center. A vaulter performed a series of predetermined exercises in the following order: Mount on, Basic seat, Stand, Jump from forward stand, Forward swing, Backward swing, Ground jump to the inside, Ground jump to the outside, Sideways prince on the neck, Forward kneeling on the croup, and Handstand in the grips [1].

All tests were recorded with a camera (GoPro Hero 8, GoPro, Inc., 3025 Clearview Way, San Mateo, CA 94402, USA) attached to the front of the lunger. Another camera (Sony HDR CX625, Sony Europe B.V., The Heights, Brooklands, Weybridge, Surrey, KT13 0XW, United Kingdom) was installed outside the circle in a position that simulated the position of the judge in a competition (Figure 1). This camera filmed each performance from the mount-on of the vaulter until the completion of the final exercise.

The horses wore their regular equipment used for vaulting. As in competition, the horse presented itself with a correctly adjusted bridle and the correct position of the surcingle and a pad. With the side reins properly adjusted, the horse can carry its nose correctly on or slightly in front of the vertical [1]. The side reins were adjusted in accordance with the FEI's Vaulting Rules ("With the side reins properly adjusted, the horse can carry its nose correctly on or slightly in front of the vertical."). In order to allow the horse to bend on the circle, as usual, the lungers adjusted the inside rein to be slightly shorter than the outside rein. The difference in length between the two sides was at the discretion of the lunger.

In order to ensure the quality of the reins' adjustment, an experienced investigator analyzed the images from the camera fixed on the lunger to evaluate the head-neck and neck-trunk angles with the Kinovea® software.

They were also fitted with an inertial measuring unit (IMU) (Opal sensor, 6 g, APDM Wearable Technologies Inc., 7204 SW Durham Road, Suite 800 (Bldg. Q), Portland, OR 97224, USA) attached to the surcingle against the sternum. The sensor included a 3-axis accelerometer, a 3-axis gyroscope, and a 3-axis magnetometer. The sampling frequency was 128 Hz, and the accelerometers were configured in a high-6-g mode. The horses were warmed up before entering the arena for the test. Before starting the recording, the horse/lunger combination had one minute to acclimatize to the arena and the type of side reins. All horses were recorded with two types of side reins in a randomized design. The side reins joined the bit ring and the surcingle. They were either all-leather side reins ("Without elastic"), made entirely of leather, or side reins with a small elastic part ("With elastic"), made of leather with an elastic piece measuring 6 cm. The two rein types are both permitted in competition. Between each rein type, the horses' mouths were checked for lesions, and the horses were hand-walked for five minutes without side reins.

A duration of 1 min 30 s of left-lead canter without a vaulter was recorded. The left-lead canter was the gait most commonly chosen by competitors. The horses worked on a circle with a lunge line measuring 14 ± 1 m in length. The mean speed of the left-lead canter was 4 ± 0.5 m/s, and the mean stride frequency was 1.6 ± 0.1 strides/s.

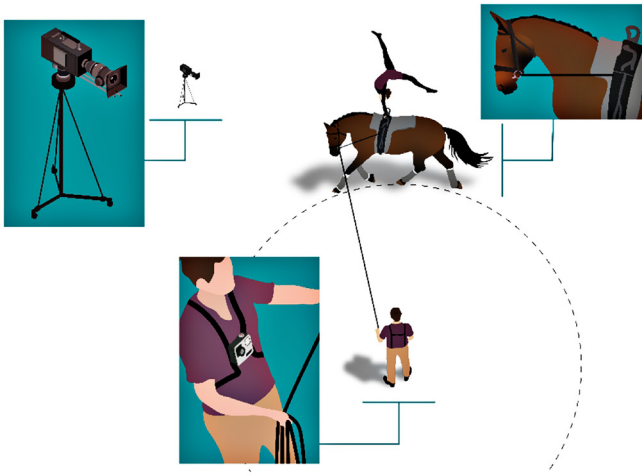


Figure 1: Diagram of the experimental setup. The lungers wears a camera (GoPro Hero 8) attached to a harness around the chest. A tripod-mounted camera (Sony HDR CX625) is positioned outside the circle, in the judge's location during a competition. The horse is equipped with side reins connecting the bit and the surcingle on a pad, which is standard equipment required for competition. An IMU is fixed to the surcingle against the horse's sternum.

The head and neck positions showed a head–neck angle of $91^\circ \pm 9^\circ$ and a neck–trunk angle of $178^\circ \pm 9^\circ$. These values were measured from the zygomatic arch, the withers, and the base of the tail using still images obtained from the camera worn by the lungers during a canter stride. The angles were evaluated using Kinovea® software for each image of a complete stride. The selected angle value was the average of each value during a stride. As described in the FEI rules, the nose was near the front of the vertical axis, with a mean angle of $-2^\circ \pm 9^\circ$.

2.3. Ethical Statement

The study was approved by the FEI (Vaulting) and did not require study-specific permission, given that this research was non-invasive and the test setup corresponded to a regular training session. The reins tested were part of the horses' normal equipment. The behavioral observations of the horses were carried out in compliance with the ethical guidelines of the International Society for Applied Ethology. This research was non-invasive.

Chief trainers of the testing stations, as well as the owners, the lungers, and the vaulters, volunteered their horses to participate in the study. They all signed an informed consent form beforehand. If the participant was a minor, one of the two parents signed. No personal data were collected. The age and number of years of practice were collected from the FEI website (<https://www.fei.org/vaulting/athletes>) [8]. The data were anonymized for analysis.

2.4. Mouth Examination

An examination of the horse's mouth before and after each test was carried out by a qualified FEI veterinarian equipped with disposable gloves. The examination consisted first of palpating the upper and lower bars, looking for sensitivity or injuries, and secondly, with the mouth open and the tongue

held in place, checking for injuries to the mandibular bars, the lips, the corners of the mouth, and the tongue. These examinations ensured respect for the physical integrity of the horse and the quality of the data collection. A form was filled out for each test, and the results were communicated immediately. No oral injuries were reported during the study.

2.5. Data Collection

2.5.1. The Judges' Scores

A total of 66 videos (33 horses/two types of side reins) were obtained. Five international judges scored the videos in a randomized order without knowing the name of the horse, the vaulter, or the nationality. Complete blinding was not possible. For each video, the judges gave seven scores (scores ranged from 0 to 10, with 10 indicating the highest level; one decimal place was allowed). The parameters were scored as defined by the FEI Vaulting Guidelines (Table 1).

2.5.2. Locomotor Parameters

The IMU was taped to the surcingle at the level of the sternum. It was the preferred position for estimating movements of the center of gravity that affect the distribution and intensity of loads on the horse [5,9]. From a biomechanical point of view, the trunk segment is considered to be a non-deformable segment.

The sensor records acceleration data on the z-axis (dorso-ventral direction of movement pointing upward), the x-axis (horizontal direction of movement pointing backward), and the y-axis (lateral direction of movement pointing to the right), as well as rotation angles around the three-dimensional axes (roll, pitch, and yaw angles). For each of the 66 tests, the measurements described in Table 2 were calculated from the IMU recordings.

2.6. Statistical Analysis

The statistical analysis was carried out on 65 recordings, including two recordings per horse (one with each type of side rein) and the seven scores from each judge for each recording. One horse was recorded with only one type of side rein.

Descriptive statistics were carried out for the variables, and after a normality test (Shapiro–Wilk test), Spearman's correlation analyses were used to assess the linear relationships between each variable, IMU sensor measurements, and judges' scores. Results were considered statistically significant at $P < 0.05$. Correlation coefficients with $|r| > 0.6$ were interpreted as indicating moderate to strong correlations, and as very strong when $|r| > 0.8$; as fair when $0.3 < |r| < 0.5$; and as poor when $0.1 < |r| < 0.2$.

A classification using the k-means method on the canter (A1) + Vault-ability (A2) score was carried out (Supplementary Materials) [10]. The horses in one group were the highest-scored horses ("correct canter group"), and the horses in the second group were the lowest-scored horses ("incorrect canter group"). A Mann–Whitney U test ($P < 0.05$) was performed to determine whether there was a significant difference in locomotor parameters between the two groups without multiple post hoc comparisons. All statistical analyses were performed using XLSTAT 2023.3.0 (Lumivero, 2025), an XLSTAT statistical and data analysis solution. <https://www.xlstat.com/fr> with a significance level of $P < 0.05$.

Table 1: Judges' score definitions.

Parameter	Definition
Rhythm	The characteristic sequence of footfalls and timing of a pure canter with a clear beat and a clear moment of suspension.
Relaxation	The horse's mental state (calmness without anxiety or nervousness), as well as its physical state (the absence of negative muscle tension).
Connection	Through the body to the contact on the side reins (acceptance of the bit (or cavesson) through acceptance of the aids), when the energy generated in the hindquarters by the driving aids flows through the whole body of the horse and is received in the side reins and lunge line, referred to as the "bridge of engagement."
Impulsion	The transmission of an eager and energetic, yet controlled, propulsive thrust generated from the hindquarters into the athletic movement of the horse. Impulsion is associated with a phase of suspension. It is measured by the Horse's engagement of its hind legs and desire to carry itself forward with a lowering of the croup, elasticity of its steps, suppleness of its back, and increased lightness of the forehand.
Straightness	The horse is straight when the footfalls of the forehand and the hindquarters are appropriately aligned and when its longitudinal axis is in line with the track on which it is lunged.
Collection	The horse lowers and engages its hindquarters and shortens and narrows its base of support, resulting in lightness and mobility of the forehand and self-carriage.
A1	The average of the six subscores listed above makes up Score A1. A1 represents 60% of the total score for the horse.
Vault-ability (A2)	The horse must give the impression of carrying out the test of its own accord and maintaining true balance and self-carriage. There is an impression of harmony and lightness throughout the test. A2 represents 25% of the total score for the horse.

Table 2: Canter calculated variables.

Variable	Biomechanical definition	Requirement described in the judging guidelines
Mean longitudinal balance: LgB (°)	Mean trunk angle in the sagittal plane (relative to the position before the start). It represents the average balance between the shoulders and the hips of the horse per stride, as reflected by the trunk segment as a non-deformable segment; positive values represent flexion of the trunk ("balance on the shoulders"), and negative values represent extension of the trunk ("balance on the hips"). (Figure 2).	This mean posture is linked to balance on the shoulders if the horse's trunk is in flexion, with the withers as the lowest point, or to balance on the hindquarters (collection) if the trunk is in extension, with the withers as the highest point.
Mean lateral balance: LaB (°)	Mean trunk angle relative to the position before the start. It represents the average left/right balance of the horse per stride; negative values represent a lean to the left, and positive values represent a lean to the right.	Position and movement in the horizontal plane most closely correspond to the straightness score. The guidelines describe an observation of the mean lateral balance at an almost vertical body angle. The results should therefore show a link between straightness and mean lateral balance.
Roll body lean angle: Roll (°)	Roll angle of the rotation around the longitudinal axis.	
Pitch body angle: Pitch (°)	Pitch angle of the rotation around the mediolateral axis.	The guidelines describe stability in balance; therefore, a low pitch value is expected.
Elevation (cm)	Range of vertical displacement of the horse's trunk per stride (using the method for deriving displacement [11]).	Clear moment of suspension. Suppleness through the back.
Propulsion (m/s ²)	Mean vector of propulsion during the stance phase (when dorsoventral acceleration was negative and longitudinal acceleration positive).	The guidelines describe a canter with energetic strides and clear impulsion from the engaged hindquarters.
Braking (m/s ²)	Mean vector of braking during the stance phase (when both accelerations were negative).	
Braking time (s)	Mean time spent braking during the support phase per stride.	
Propulsion time (s)	Mean time spent in propulsion during the support phase per stride.	
Canter quality index (m/s ³)	Integral of a Fast Fourier Transform of the first two harmonics ($\pm$ frequency/2) (Figure 3). The lower the value, the more regular the three beats. A high value could represent a diagonal dissociation, i.e., a short temporal separation of the limbs of the diagonal pairs at contact and/or lift-off.	Regularity and a clear three-beat canter.

3. Results

The distribution of the judges' scores is shown in **Figure 4**. Only Collection and Connection were normally distributed (Shapiro–Wilk test). A few scores were far from the median. Descriptive statistics for locomotor parameters are presented in **Table 3**.

3.1. Correlation

Results of the correlation tests between the variables are shown in **Figure 5**. The correlation analysis showed that all the scores were highly correlated. All the scores were correlated with the same locomotor parameters, and the quality index was inversely correlated with all the scores. Correlations for each of the scores with the locomotor parameters are described in **Table 4**.

Analysis of the correlations between selected locomotor variables revealed a statistically significant relationship close to the significance threshold, with a low correlation coefficient. Although statistically significant, this relationship remains poor and should therefore be interpreted with caution because it is of limited practical relevance. A horse in extension was more stable ($r = -0.247$, $P = 0.047$), with more propulsion ($r = -0.246$, $P = 0.049$), and the more the horse propelled, the higher the elevation ($r = 0.284$, $P = 0.022$). Obviously, propulsion and braking are linked: the more time the horse spends braking, the less time it spends propelling.

3.2. Analysis of Variance

An analysis of variance (Mann–Whitney U test) on the two groups formed from a k-means test on A1 + A2 scores differentiated higher-scoring horses ("Correct canter" group) and lower-scoring horses ("Incorrect canter" group) by elevation (14 ± 1 cm vs. 13 ± 2 cm, $P = 0.013$), propulsion (6.7 ± 1.4 m/s² vs. 5.7 ± 1.7 m/s², $P = 0.005$), and a clear regularity of the three beats (0.016 ± 0.004 m/s³ vs. 0.019 ± 0.004 m/s³, $P = 0.018$) (**Figure 6**).

4. Discussion

Many sports, such as gymnastics, diving, ski jumping, and figure skating, use judges' scores to determine the winner

of a competition. These judges use discipline-specific rating scales when judging performances (for example, 0.000–10.000). This is the case for vaulting judges, and one judge (out of four judges) is responsible for scoring the Rhythm, Relaxation, Connection, Impulsion, Straightness, and Collection of the canter with scores between 0 and 10; one decimal place is allowed. The average of the six scores constitutes A1. This A1 score is combined with the vault-ability (A2) of the horse, which represents 25% of the horse's final score, and the Lunging score, which represents 15%, for a total Horse Score. A3 was not scored by the five judges in this study, as the aim only concerned judging horse locomotion.

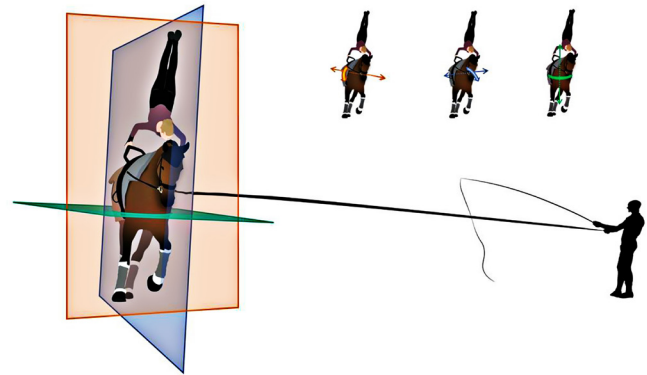


Figure 2: Representation of the three planes: Frontal plane in orange: This plane divides the trunk into front and back parts. In this plane, the horse performs movements of inclination, and the oscillation around the longitudinal axis of the trunk is rolling. Sagittal plane in blue: This plane divides the trunk into right and left parts. In this plane, the horse performs movements of flexion (movement of the trunk downward) and extension (movement of the trunk upward), and the oscillation around the mediolateral axis is pitching. Transversal or horizontal plane in green: This plane divides the trunk into upper and lower parts. In this plane, the horse performs movements to the left and right, and the oscillation around the vertical axis of the trunk is yawing.

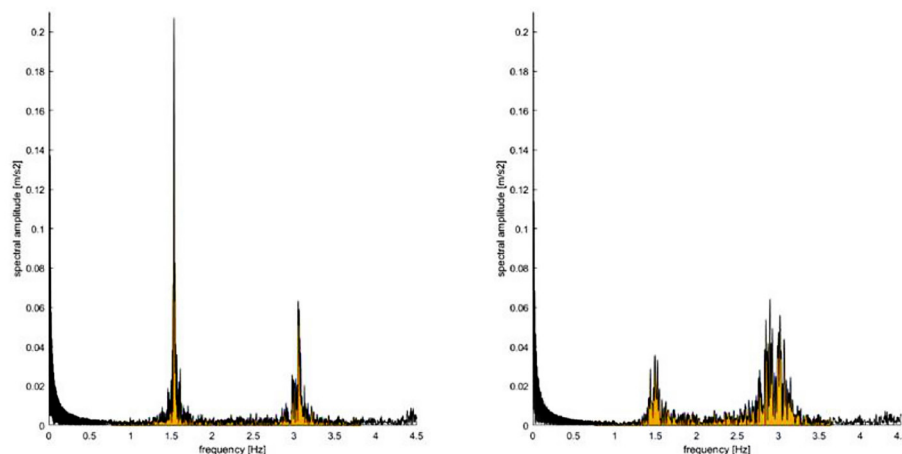


Figure 3: Fast Fourier transform of a correct canter quality index on the left and an incorrect one on the right. The yellow area represents the calculation of the canter quality index. The larger the area, the more irregular the canter.

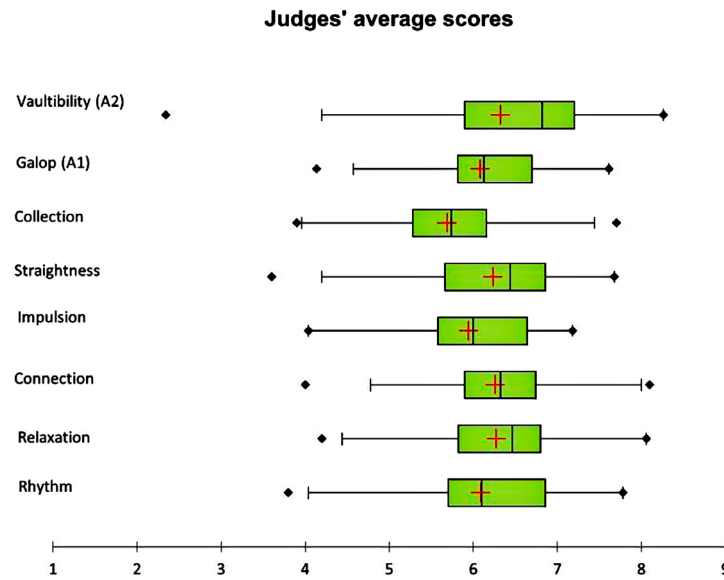


Figure 4: Box plot of the judges' scores.

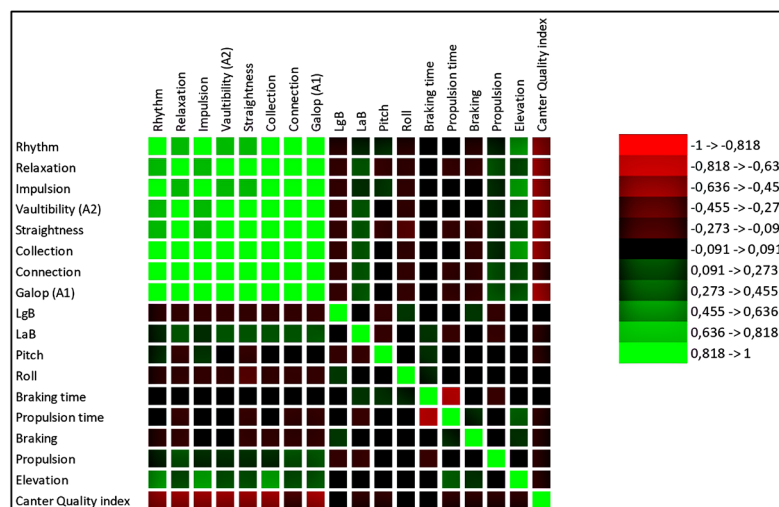


Figure 5: The Correlation plot displays significant correlations between the judges' scores and the locomotor parameters. Positive correlations are shown in green, and negative correlations are shown in red. Black indicates no correlation.

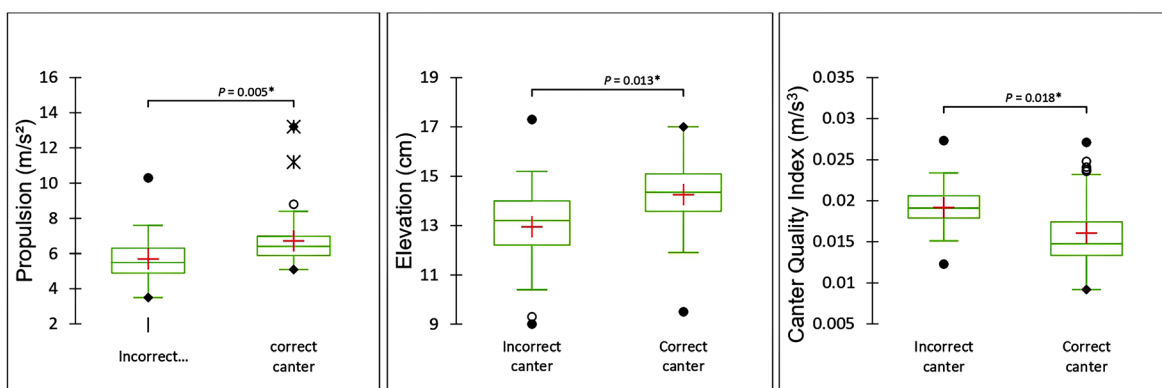


Figure 6: Boxplot of the three locomotor parameters that distinguished correct canter quality from incorrect canter quality. A correct canter was characterized by greater propulsion and elevation compared with an incorrect canter, and a lower quality index, indicating a better canter.

Table 3: Mean $\pm$ sd of locomotor parameters. Values in brackets are mean (95% CI).

Variable	Mean $\pm$ sd (95% CI)
LgB (°)	-8 ± 5 (-9 , -7)
LaB (°)	-11 ± 5.5 (-13 , -10)
Pitch (°)	13 ± 2 (13 , 14)
Roll (°)	10 ± 2 (9.5 , 10.5)
Braking time (s)	0.18 ± 0.03 (0.17 , 0.19)
Propulsion time (s)	0.14 ± 0.04 (0.13 , 0.15)
Braking (m/s ²)	7 ± 0.8 (6.7 , 7.2)
Propulsion (m/s ²)	6.5 ± 1.5 (6.1 , 6.8)
Elevation (cm)	14 ± 2 (13.5 , 14.3)
Quality index (m/s ³)	0.017 ± 0.004 (0.016 , 0.018)

The results showed a strong correlation between the six scores in A1 (and A2): a horse judged to be correct only received good marks (**Figure 4**). This may suggest that the judges assessed the overall quality of the canter rather than focusing on each of the six specific scores, or that the scores are linked and thus, if one goes up, the other scores follow. This refers to the complexity of judging without numerical data. The high number of canter quality criteria to be scored in one minute by a single judge may give rise to bias [12–14] and requires a great deal of knowledge of horse locomotion. An assessment of seven (or more) scores without any numerical data has been reported to be beyond human cognitive capacity [15]. As in dressage, judges rely on simpler cognitive strategies to make decisions, which can lead to errors of judgment [4], such as breed bias or the fact that some judges systematically give high marks and others low marks.

According to the judges, a correct vaulting horse canter was distinguished from an incorrect one by the activity and the regularity of the three beats. The group of correct canters, determined by the judges' scores using the k-means method, was characterized by good activity and regularity in the three-beat canter. Conversely, the group of incorrect canters, determined by the judges' scores, was characterized by poorer activity and regularity. Moreover, each score was correlated with the elevation and regularity of the three beats. Elevation and propulsion were two canter performance criteria that have already been demonstrated in dressage horses [4].

Balance in the sagittal and frontal planes can also be relevant observables [1]. They correlated well with the judges' scores. The horse has to show collection by lowering and engaging its hindquarters. The forehand is lightened as a result of the better balance; therefore, the horse will be able to move its forelimbs more freely and reach higher and farther forward. The collection of a gait means that forward movements become upward movements. This was demonstrated in the collected trot [3]. Propulsion and elevation were the consequence of good balance.

The horses with a lower leaning angle were scored better. When a horse moves in a circle, its body leans inward due to centripetal forces. This inclination allows the vertical resultant of the ground reaction force to remain outside the circle [16]. The degree of inclination depends on both the circle size and the speed. In this study, at a speed of 4 ± 0.5 m/s on a 16 m diameter circle, the mean inclination angle of the horses was $11 \pm 5.5^\circ$. Like in dressage [6], trained vaulting horses learn to maintain the vertical orientation of their body in order to support the vaulter. This observable was correlated with the straightness score. Indeed, on a left circle, the horse must show lateral bending to the left, developed in the horizontal plane around a dorsoventral axis, which influences hind limb placement and can serve as a visual indicator [17]. Good straightness offers good stability in the mediolateral plane for the execution of the vaulter's exercises [18]. It is also known that horses must stabilize their trunk, neck, and head to maintain a spatial frame of reference [19]. One might therefore have expected a correlation between the straightness score and lateral bending (LaB), but this was not observed in the present study. This could indicate either that the IMU calculation does not accurately reflect whole-body lateral bending, or that the judges did not evaluate it correctly [9].

This correlation between all the scores may reflect the scale of progression proposed in the rules [1], which should make it possible to assess the quality of a performance objectively. The progression is organized into three main phases, the order of which is fundamental. Thus, a horse that is collected, the highest criterion on the scale, is balanced, with impulsion, and regular in its beats. According to this scale, a horse could have a poor score for collection, but a good score for regularity of the beats. However, this was not the case in this study; a horse with a poor collection score had a poor regularity score systematically. In addition, the guidelines specify that scores must be distinct. For example, a horse may show poor rhythm with an unclear three-beat canter (lower A1), but may still work with completely consistent speed and energy (higher A2). It seems unlikely that all 33 horses would have been either good or bad for all six scores, indicating that either the details of the six A1 scores are redundant, or the judges are not able to separate the judging of the scores. The fact that several of the scores were correlated with the same locomotor parameters shows that the assessment of these separately may be redundant and that a simplification, such as reducing the number of scores, might be possible.

The quality index calculated in this study seemed to be of major significance to the judges. This index should reflect the distortions of the dorsoventral accelerometric signal and consequently evaluate the regularity of gait and even modifications of the three beats. During the test with the vaulter, the two major faults in the quality of the canter are a lack of projection and a desynchronization of the diagonal, which must be penalized by the Rhythm score, which inevitably has an impact on the A1 score. This was the case in the study. As the other locomotor parameters were not correlated with this index, an in-depth biomechanical study of these two faults should be undertaken in order to detect them visually.

Table 4: Correlations between scores and locomotor parameters. Only significant correlations ($P < 0.05$) are reported.

	Rhythm	Relaxation	Connection	Impulsion	Straightness	Collection	Canter (A1)	Vault-ability (A2)
Quality index	-0.550 (<0.0001)	-0.502 (<0.0001)	-0.441 (<0.0001)	-0.513 (<0.0001)	-0.467 (<0.0001)	-0.441 (<0.0001)	-0.504 (<0.0001)	-0.564 (<0.0001)
LgB	-0.269 (0.030)	-0.258 (0.038)	-	-0.266 (0.033)	-	-	-0.252 (0.043)	-
LaB	0.245 (0.050)	0.303 (0.015)	0.372 (0.002)	-	0.384 (0.013)	0.324 (0.009)	0.330 (0.008)	0.360 (0.003)
Elevation	0.529 (<0.0001)	0.301 (0.015)	0.377 (0.002)	0.525 (<0.0001)	0.276 (0.027)	0.456 (<0.0001)	0.411 (0.001)	0.369 (0.003)
Propulsion	-	0.305 (0.014)	0.322 (0.009)	-	0.269 (0.030)	0.251 (0.044)	0.279 (0.025)	-
Roll	-	-	-	-	-0.282 (0.002)	-	-	-

4.1. Limitations

The main limitation in the current study design is that the scoring was done using videos. We know that the visual angle from which the sporting situation is perceived influences judgment. Even if the camera was placed in the same place as a judge's table, the information perceived visually is limited, particularly when it comes to assessing the speed of movements [12]. In addition, the potential public pressure, which is part of the judging process, is not taken into account here. Scores can also be biased by the automation of certain evaluation routines, especially for a large number of videos, with an effect of the order in which the performances are viewed [13]. As in the case of live judging, the participating judges were international-level expert judges, and we know from previous studies in other disciplines that there is a risk of bias among expert judges, such as overpersonalized expectations of some athletes highlighted in, e.g., gymnastics [14]. The videos provided were not nominative, but the fact that they were international judges and international athletes made anonymizing impossible. These biases were illustrated by the results of the interjudge agreement analysis, particularly the more severe assessment by one of the five judges.

Measurements of canter quality were carried out with the vaulter, as in competition, in this study. To extend this analysis, it would be relevant to compare the locomotor parameters of the canter with and without the vaulter. As with the rider–horse interaction, the vaulter probably has an impact on locomotion, whether beneficial or not [20,21].

5. Conclusion

The FEI rules propose six distinct scores to assess the quality of the canter: rhythm, relaxation, connection, impulsion, straightness, and collection, and a separate score for vault-ability. They were all correlated and therefore non-discriminatory, and several were correlated with the same locomotor parameters. On the basis of the results, a simplification of the number of scores can be discussed. The results showed that, for judges, a correct quality of canter was a canter with propulsion, elevation, and good regularity of the three beats. Balance in the sagittal and mediolateral planes should be retained as an observable measure of performance. All of these observables seem to be decisive and sufficient to assess the quality of the canter and are interesting

from the point of view of decision support within the framework of the initial and ongoing training of judges.

Supplementary Materials

Supplementary Materials present details of the k-means classification of canters based on the combined A1 and A2 judges' scores, including cluster validation metrics.

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Authors' Contributions

S.B.: Conceptualization, Methodology, Formal analysis, Resources, Data curation, Writing – original draft, Writing – review & editing, Supervision, Project administration. E.P.: Conceptualization, Formal analysis, Resources, Data curation, Writing – original draft, Writing – review & editing. R.DB.: Conceptualization, Resources, Writing – original draft, Writing – review & editing. L.C.B.: Conceptualization, Resources, Writing – original draft, Writing – review & editing. I.B.: Conceptualization, Methodology, Project administration. All authors have read and agreed to the published version of the manuscript.

Data Availability

The authors confirm that all data underlying the findings are accessible without restrictions. Data can be obtained upon request from the corresponding author.

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Conflicts of Interest

The authors declare that there are no conflicts of interest.

Ethical Approval

The study was approved by the FEI (Vaulting) and did not require study-specific permission. The data were anonymized for lungers, vaulters, and horses.

Consent to Participate

Chief trainers of the testing stations, as well as the owners, the lungers, and the vaulters, volunteered their horses to participate in the study. They all signed an informed consent form beforehand. If the participant was a minor, one of the two parents signed. No personal data were collected.

Declaration of Generative AI and AI-Assisted Technologies

During the preparation of this work, the authors used DeepL Translator to improve the translation of the text. Following the use of this tool, the authors reviewed and edited the content as needed and take full responsibility for the final version of the publication.

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