

Head–Neck Positions in Ridden Horses: Defining Degrees of Flexion and Their Impact on Equine Behavior and Welfare

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Abstract

Horse sports face public scrutiny, particularly regarding concerns about horse welfare. Understanding how the physical positioning of the horse's head and neck while being ridden affects behavior is crucial for improving welfare standards. This study aimed to investigate the influence of head–neck position (HNP) in ridden horses—specifically, the vertical and poll angles—on conflict behavior (CB). Furthermore, it aimed to identify a critical threshold at which HNP significantly affects behavioral outcomes. Elite dressage horses were observed during warm-ups and tests at competitions, and horses presented in educational videos were analyzed to examine the relationship between HNP and CB. A total of 191 rides were analyzed, HNP parameters (angle to the vertical of nasal plane, poll angle, and shoulder angle) and CB indicators (e.g., unusual oral behaviors and tail swishing) were recorded over 3-minute intervals using Observer XT (Noldus). Data were analyzed using general linear mixed-effects models, with CB (sum of all behaviors) as the response variable and horse-rider-ID as a random effect. Both poll and vertical angles had significant negative effects on CB, indicating that horses exhibited more CB when these angles decreased ($p < 0.001$, $df = 139.64/137.28$, respectively). Shoulder angle also had a significant impact on CB in one model ($p = 0.014$, $df = 136.61$). A vertical angle of -7.5° behind the vertical was identified as the cut-off value associated with an increase in CB. Stallions exhibited more CB than mares and geldings ($p < 0.001$, $df = 73.16$). The models demonstrated good fit, with consistently non-significant effects of age, breed, and bit type. Optimizing HNP during riding is crucial for enhancing behavioral well-being and the overall welfare of dressage horses in competitive settings.

Keywords

Head–neck position; equine; behavior; riding; hyperflexion; Rollkur

1. Introduction

Horse sports are in the spotlight of public debate because of serious concerns about horse welfare. Ultimately, these concerns jeopardize the sports' social license to operate [1,2]. Public critique is directed toward numerous equestrian disciplines, including dressage, and the horse industry itself has called for urgent welfare improvements to ensure the long-term sustainability of the sport (e.g., [3]). Scientific data support this negative image, showing that an alarmingly

high number of horses compete with mouth injuries [4–7] and exhibit conflict behaviors such as mouth opening or tail swishing [8–11], which likely indicate discomfort, stress, and/or pain. Other studies have frequently reported the use of controversial head–neck positions (HNPs) during riding, where horses are subjected to 'rollkur' or 'hyperflexion' or the so-called 'low, deep, and round' (LDR) posture. These techniques involve over-flexion of the horse's neck and head and most likely lead—regardless of riders' skill levels—to reduced welfare [12].

Yet, despite national competition rules—for example, those of the German Equestrian Federation [13], Equestrian Australia [14], and Swiss Equestrian [15]—and international rules of the Fédération Équestre Internationale [16] that clearly define acceptable HNPs (i.e., with the nasal plane slightly in front of or at the vertical), scientific studies have consistently reported that two-thirds of observed competition horses are ridden with the nasal plane behind the vertical [8,9,17–21]. Moreover, despite these regulations, such HNPs are frequently rewarded with higher competition scores [19,22].

Undesirable or unwanted changes in behavior, such as so-called 'escape' or 'avoidance' behaviors, can be summarized under the umbrella term 'conflict behavior.' These behaviors (e.g., shying, bolting, bucking, rearing, head-tossing, tail swishing, mouth opening, putting the tongue out of the mouth, or over the bit) typically indicate conflicting motivations between the horse's interests (e.g., freedom from pain) and the rider's demands [23,24]. They may result from frustration, confusion due to competing signals given by the rider [25], or discomfort and/or pain [26,27]. Consequently, horses exhibiting conflict behaviors are likely experiencing difficulties in coping with mental and/or physical discomfort [28]. Evidence links different conflict behaviors and facial expressions to negative emotions [29–32]. For example, numerous studies provide evidence that tail swishing and oral behaviors are indicators of stress and potential pain [7,20,26,33–36].

It has been shown that horses subjected to riding techniques that position the nasal plane behind the vertical exhibit signs of discomfort, reflected in various conflict behaviors [12,22,33]. In contrast, horses ridden with conventional poll flexion, where the nasal plane predominantly remains in front of the vertical, show fewer signs of conflict behaviors [8,12,33]. Horses not only express higher levels of conflict behavior when ridden in rollkur/hyperflexion, but also avoid rollkur when given the choice [37,38]. Scientific studies further suggest that flexion of the neck can compress the ventral neck structures, including the pharynx, larynx, and parotid glands [39–43], potentially leading to negative physiological effects. Additionally, the space between the neck and head, known as the gullet, can be quantified by the poll angle. A smaller poll angle reduces the available space, thereby restricting the function of the ventral respiratory and digestive organs [12].

One key structure in the ventral neck is the *m. brachiocephalicus*, a muscle that plays a role in head flexion. Research has indicated that this muscle alters its natural activity pattern and exhibits increased activity when the horse's neck is put in a hyperflexed position [8]. This finding supports earlier work [44] that observed increased single fiber activity in the *m. serratus ventralis* (a muscle that suspends the trunk between the forelimbs) during hyperflexion.

Furthermore, a restricted vision has been proposed as a contributing factor to the increased discomfort experienced during rollkur. This restriction may lead to heightened levels of fear responses attributed to elevated arousal or anxiety in horses subjected to rollkur compared to those ridden with normal poll flexion [33,38]. Interestingly, relatively minor flexion of the horse's head and neck resulting in a nasal plane

at 10° behind the vertical results in increased conflict behavior and elevated physiological parameters (e.g., lactate, pleural pressure, upper airway tract abnormalities), compared to when the nasal plane is slightly (5°) in front of the vertical [36]. In response to evidence highlighting the negative impacts of rollkur on horse welfare, Switzerland has introduced the first legal measures to prevent the "excessive bending of a horse's neck or back" [45] and has explicitly prohibited rollkur [46]. However, enforcing this legislation in practice is challenging due to the lack of precise definitions of what constitutes 'excessive flexion,' resulting in the absence of any officially announced sanctions against riders competing in Switzerland under this law since its implementation.

This study examined the influence of HNP on behavior by analyzing the full range of head–neck positions used in practice, based on direct angle measurements without categorization, in a sample of horses ridden in dressage during warm-up for competitions, in competition tests, and in educational videos. The aim was to assess their potential impact on equine welfare as reflected in the occurrence of conflict behaviors. Recognizing the need for a comprehensive industry standard, this study also aimed to objectively define the critical angles at which HNP may jeopardize equine welfare to support riders, judges, and other stakeholders in making evidence-based decisions about horse welfare when evaluating training and competition practices.

It was hypothesized that:

1. The degree of head–neck flexion, specifically at the vertical and poll angles, influences behavioral parameters, implying that greater flexion correlates with increased prevalence of conflict behavior.
2. The poll angle was expected to have more influence on conflict behavior than the vertical angle of the nasal plane.
3. The smaller the shoulder angle or the higher the head is held, the greater the negative impact of flexion on the frequency of conflict behavior.
4. There is a critical 'cut-off value' for the negative influence of neck flexion on a horse's well-being, suggesting that once the vertical and poll angles exceed a certain threshold, conflict behavior increases significantly.

2. Materials and Methods

2.1. Horses and Riders

This study involved no experimental manipulation or rider instruction; it relied solely on unobtrusive video recordings of actual events at publicly accessible competition venues. Data were collected at dressage competitions at three locations: 1) in Aachen (Germany) during warm-up and competition tests, 2) in Bern (Switzerland) during warm-up, and 3) in Avenches (Switzerland) during warm-up and competition tests. Additionally, 4) educational rides were studied from videos via the online platform WeHorse (www.wehorse.com), demonstrating dressage training.

A total of 191 rides were included in this study (Table 1). Details (e.g., sex, age, and breed) for the majority of horses were specified in the competition start lists. The horses were on average 12.9 years old (SD ± 3.5).

The rider-horse pairs were either competing at low to medium levels (levels A, L, and M) or up to the highest levels (levels S and Grand Prix Special) in dressage, or they were ridden in dressage by renowned competitors to showcase training methods for educational and demonstration purposes. In the latter case, the performance level was assigned according to the movements and exercises classified in the German competition guidelines [13], as shown in the respective video. Young horses up to 6 years old were only studied in levels A to M, as they are restricted to lower competition classes until they reach the required age for higher levels.

Background details on the sex, age, and breed of the horses were obtained through the start lists published by the competition organizers, but this information was not available for the 24 horses showcased for educational purposes. However, some background details could be found via the internet due to the popularity of some of these riders and their horses. Mares could be identified in these samples, but stallions and geldings could not be distinguished. One of the WeHorse platform's rides was part of a high-level (S) competition, so it was classified as a competition rather than education. In the dataset, 46 riders appeared twice, 5 riders three times, 9 riders four times, and 3 riders five times. For horses, 62 appeared twice, 2 appeared four times, and 2 appeared five times.

In the context of international dressage competitions (Grand Prix Special, CDIO 5*) in Aachen, Germany, all horses were vetted by veterinarians as 'fit to compete' according to international FEI rules [16]. In the context of national dressage competitions (low to high-level A–S in Avenches and Bern, Switzerland), random veterinary checks were undertaken according to the national rules. Stewards (during warm-up) or judges (during competition) were always present and had the authority to remove horses suspected of injury. Only horse-rider pairs that passed the veterinary checks or were not called out by stewards or judges were allowed to participate in the competition. Thus, all horses included in this study had been judged to be healthy. In the context of online video footage (WeHorse platform), the scientific observer, highly experienced with horses, made a subjective evaluation, excluding any horse from the analysis if signs of lameness were visible, though this was not necessary for the current sample. Hence, only horses deemed sound were included in the dataset. No information was available on other potential health issues, such as oral discomfort or subclinical conditions, for any of the included horses.

Equipment was recorded in terms of whether the horse was wearing a snaffle or double bridle. However, there was no information available on the tightness of the nosebands, except that Swiss rules require a 1.5 cm gap between the nasal bridge and the noseband, while FEI rules stipulate that two fingers should fit between the noseband and the side of the horse's mouth. It is unknown whether these rules were adhered to in practice.

Table 1: Overview of study-specific details, including study location and number of rides analyzed at each location (n = 191), breed and sex of horses, equipment used, and level of performance.

Category	Description	Total (n)
Location	Aachen (GER)	99
	Bern (CH)	16
	Avenches (CH)	52
	WeHorse	24
Situation*	Warm-up	100
	Competition	68
	Education	23
Level	Elite (CDIO5*)	100
	High (S)	40
	Medium (Young horses, M)	39
	Light (Young horses, L)	12
	Beginner (Young horses, A)	9
Breed	Royal Dutch Sport Horse (KWPN)	29
	German Warmblood	62
	Iberian Breeds (Pura Raza Española, Lusitano)	11
	Swiss Warmblood	56
	Other Warmblood	15
	Unknown**	18
Sex	Stallion	49
	Gelding	103
	Mare	23
	Unknown**	16
Bit used	Double bridle	139
	Snaffle	52

*Situation refers to the condition under which the sample was taken: at the warm-up area before the competition (warm-up), the competition itself (competition), or from videos provided at the online platform for educational purposes (education).

**Recorded material without information provided about horses and riders was also studied.

2.2. Data Collection

The video samples were obtained between the years 2018 and 2021. To ensure the analysis of a broad spectrum of HNPs (Figure 1), samples were collected from horses at different levels of competition and training, the latter being analogous to competition levels. The aim at each competition location was to film every rider on each starter list. However, this was not always possible due to time constraints, multiple riders in the warm-up area, and visibility issues when horse-rider pairs were frequently hidden behind other competitors and spectators during filming. For the educational videos, the

selection was based on renowned trainers ($n = 10$) known for dressage riding at the highest levels. Every suitable video of these trainers was included if it met the study criteria: a minimum duration of three minutes at trot and canter, with rein contact maintained during the working phase.

During warm-up at competitions, two observers filmed at the same time with handheld video cameras (Sony FDR-AX53, Sony HDR-CX625, recordings in HD quality at 25 frames per second), filming different horse-rider pairs in the publicly accessible warm-up arenas. Horses were always filmed from the short side of the arena from a 10 m distance. The cameras were held at shoulder height with the cameras' internal image stabilizer activated, allowing for flexibility in camera handling and positioning along the short side due to the presence of other horses/riders and spectators.

During competitions, the observers did not film any tests, but videos were obtained from the event organizers, who made the video footage publicly available. In contrast to the videos from the warm-up, one rider-horse pair was visible at a time from consistent angles in the competition test videos. This also applied to the educational videos (WeHorse), where individual horses were fully visible without any obstructions.

2.3. Data Selection

After reviewing all obtained videos in Adobe Premiere Pro (versions 2020–2023) for recording quality, minimum

lengths of continuous observation, and excluding horses deemed unfit to be ridden, a complete dataset of 191 rides was acquired.

The criteria for selecting video footage from the warm-up required each rider-horse pair to be filmed for at least six to seven minutes, allowing the extraction of a 3-minute riding segment for analysis. Phases of walking and standing still were cut out because these are often used for relaxation with long reins or for adjusting equipment. Thus, only footage showing the beginning of the working phase in trot (defined as the start of the sitting trot, in contrast to rising trot where the rider stands up and sits down in the rhythm of the trot) and canter sequences during the warm-up remained for subsequent analysis. Furthermore, sequences in which other horses or spectators crossed in front of the observed rider-horse pair were also cut out. The films were cut using Adobe Premiere Pro (versions 2020 and 2023).

The same principles of cutting the videos from the warm-up at competitions applied to the videos available from the dressage tests and the educational training videos, i.e., only the working phases were included by removing walking and standing. After reviewing and editing all obtained videos, rider and horse identities were anonymized to comply with ethical research standards and to ensure unbiased analysis.

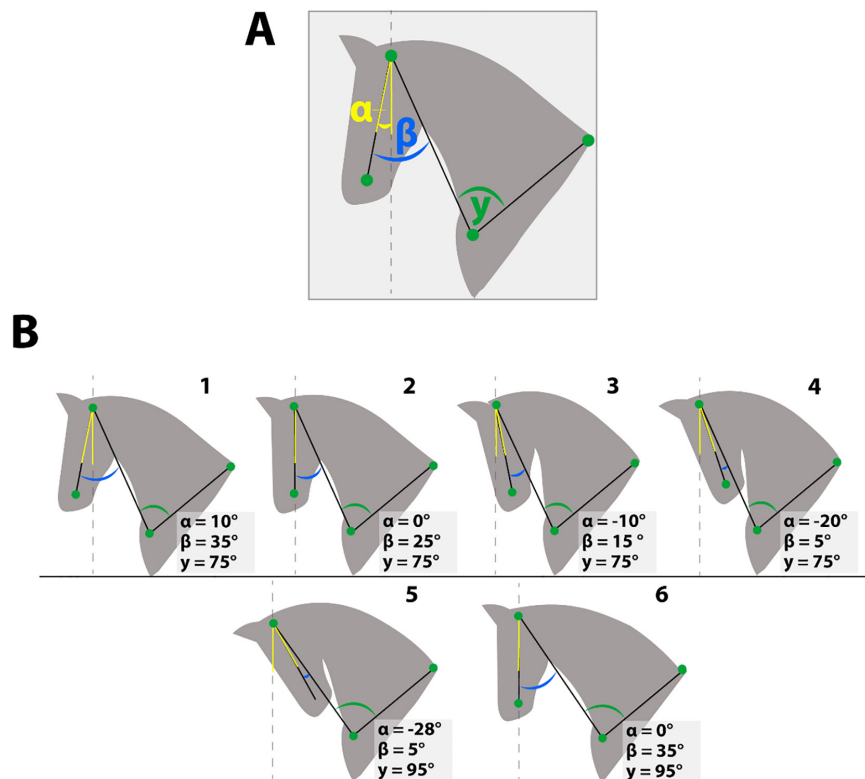


Figure 1: A) Anatomical markers (green dots) were used to measure the vertical angle (α), the poll angle (β), and the shoulder angle (γ). B) Six examples illustrating the three angles and resulting HNPs. Images 1-4: same shoulder angle but different vertical and poll angles. 1: nasal plane in front of the vertical, 2: nasal plane at the vertical, 3: nasal plane clearly behind the vertical, 4: nasal plane strongly behind the vertical, 5: larger shoulder angle and same poll angle as (4), resulting in a nasal plane strongly behind the vertical, 6: same shoulder angle as in (5) but with a larger poll angle (same as in image 1, resulting in a nasal plane at the vertical).

2.4. Data Analysis

2.4.1. Determination of Head–Neck Position

From the videos, every single frame showing a clear profile view of the horse was analyzed to determine the HNP. All video recordings were reviewed to identify scenes where the horse appeared in profile view. Using JavaScript, these segments were isolated and decomposed as individual frames, displayed at a rate of three frames per second. The observer then annotated four anatomical markers in each frame, following a consistent order (**Figure 2**). These anatomical markers were: the corners of the mouth, poll (directly behind the ears), shoulder joint, and saddle button directly above the withers. From the connections of these anatomical markers, three angles were calculated in each frame (**Figure 1**): 1) the angle of the nasal plane in relation to the vertical (vertical angle (α), 2) the poll angle (β), and 3) the shoulder angle (γ) (**Figure 1A**). JavaScript was used to automatically compile this information into a table along with frame numbers, timestamps, and coordinates of each annotated point. This process served solely to streamline the workflow by generating as many individual frames as possible. The program itself did not perform any independent actions, resulting in a total of 13,553 annotated frames and an average of 70.6 ± 36.8 (SD) frames for each sampled ride. An angle with the nasal plane in front of the vertical was defined as $\alpha \geq 0$, and behind the vertical as $\alpha < 0$, implying that the angles behind the vertical were given negative values (examples in **Figure 1B**, 3–5). The mean angles for each horse from these single frames over the 3-minute sequences were calculated and subsequently analyzed statistically.

To assess inter-rater agreement for the angular measurements, Pearson correlation coefficients were calculated based on annotations from two observers across 10 recordings, corresponding to 656 key frames for the angles α , β , and γ . The results indicated excellent agreement for α ($r = 0.959$, $p < 0.0001$) and good agreement for β ($r = 0.869$, $p < 0.001$). In contrast, γ showed a moderate correlation ($r = 0.699$, $p < 0.01$), suggesting greater variability in either the annotation process or the calculation of this specific angle.

2.4.2. Behavior

For annotating behaviors, the entire 3-minute video was observed by one observer highly experienced in observing ridden horse behavior. All occurrences of behaviors indicative of conflict according to the ethogram in **Table 2** were recorded as frequencies via the Observer XT software (Noldus, version 15) using the focal animal method [47,48]. Periods during which the horse's mouth was not visible due to the filming angle were labeled as "out of sight," and the duration of these phases was summed. To account for differences in mouth visibility resulting from individual horses performing different routines, the recorded frequencies of oral behaviors were proportionally adjusted to reflect full (100%) visibility throughout the observation period using a rule-of-three calculation.

Each video was watched at least three times by the same observer to annotate tail swishing separately from unusual oral behavior and from all other behaviors (**Table 2**).

If multiple other behaviors were observed at the same time, another annotating round was performed for that behavioral category. Some behaviors, such as unusual oral behavior, were exhibited as sustained patterns rather than discrete events (unlike tail swishing, for example), and were converted from durations to frequencies [48] to obtain comparable data (1 s = 1 count). As a result, head or nose tilting, crabbing, and unusual oral behavior could have maximum values of 180 (3×60) counts. All other behaviors could have unlimited values in theory as they were counted as occurrences (see **Table 2** for explanation).

An inter-observer reliability (IOR) test was performed to validate the standardization of the behavioral data extraction from the video material. The IOR was conducted using behavioral data recorded by an additional observer from 49 horses and resulted in a Spearman's Rank Order Correlation of 0.95 ($p < 0.01$) and a Kendall's Tau Coefficient of 0.82 ($Z = 8.32$, with a Kendall's Tau Correlation). Due to the nature of the data, it was not possible to completely blind the observers to the horses' situation and HNPs.

2.5. Statistical Analysis

All statistical analyses were conducted in RStudio Pro (version 2024.04.0+735) with R (version 4.3.3.). First, descriptive statistics on the raw data were conducted, generating histograms for the three measured angles, i.e., the vertical angle (α), the poll angle (β), and the shoulder angle (γ), as well as for the sum of all combined behaviors, labeled as 'conflict behavior.' The median and interquartile range (IQR) for each angle and behavioral parameters were calculated. Second, correlations between the three angles were assessed using Spearman rank correlations. Third, correlations between the vertical angle and conflict behavior were also examined using Spearman rank correlations.

Subsequently, factors such as sex, age, breed, and performance level were investigated to determine their influence on the prevalence of conflict behaviors. Among the behaviors listed in the ethogram, only tail swishing, unusual oral behavior, head shaking, and gait irregularities were observed. None of the other behaviors were present in the sample.



Figure 2: Still image (one single frame) from warm-up video, showing a horse in profile view. Anatomical markers (green circles) were placed on each single frame to calculate the vertical, the poll, and the shoulder angles (see **Figure 1**).

Table 2: Ethogram of recorded conflict behaviors (adapted from [8,38,49]). Each behavior was counted as one event; exceptions are indicated with superscript.

Behavior	Definition
Unusual oral behavior [*]	Includes all deviations from a still and closed mouth or chewing with closed lips, i.e., the horse opens the mouth so a gap between the upper and lower jaw is visible, shows the teeth or tongue for more than 1 second, makes chewing movements with visible separation of upper and lower jaws, or moves the lower jaw opposite to the upper while chewing.
Head or nose tilting [*]	The horse tilts its head or nose to one side.
Headshaking	The horse moves the head quickly up and down, from side to side, or both.
Going-against-reins	The horse pulls against the reins and breaks the line between the rider's elbow and the rings of the bit.
Rearing	The horse's forebody and forelimbs lift off the ground, with the hindlimbs supporting its weight while standing.
Bucking	The horse lowers the head and neck and raises the hindlimbs off the ground while standing with both front legs on the ground. While moving, see 'gait irregularities'.
Tail swishing	The horse moves the tail rapidly in vertical, horizontal, or combined directions. Each movement was counted separately, regardless of its intensity.
Crabbing [*]	The horse's hindlimbs do not follow the track of the forelimbs without intention from the rider.
Gait irregularities	Insertion of an additional step resulting in loss of rhythm. Bucking (throwing the hindquarters up simultaneously), kicking with one leg, and other hopping movements outside the specific gait while moving were included. Each deviation from the gait-specific rhythm was counted as one event.

^{*}The total time of this behavior was recorded and counted as one event per second.

To ensure comparability of the observed behaviors, their scale was adjusted using the 'norm_scale' function, which assigns values between 0 and 1. Here, 0 represents no behavioral count and 1 represents the maximum observed count for that behavior. This adjustment was necessary because gait irregularities ($n = 61$) and head shaking ($n = 9$) were observed substantially less frequently compared to tail swishing ($n = 6,461$) and unusual oral behavior ($n = 18,678$). This scaling ensured that gait irregularities and head shaking were proportionally represented relative to the two more frequently observed behaviors.

Then, a new variable 'total_conflict_behavior' was created by merging these scaled behaviors (i.e., tail swishing, oral behavior, gait irregularities, and head shaking). The 'scale' function in R was used to transform the continuous variables (i.e., vertical angle, shoulder angle, poll angle, and

age). This process centered the variables to their mean values and standardized them to units of one phenotypic standard deviation. This involved subtracting the mean of the variable and dividing the result by the standard deviation, resulting in data with a mean of 0 and a standard deviation of 1. All further statistical analyses were based on conflict behavior (sum of all recorded behaviors).

Seven linear mixed-effects models (LMMs, Models 0–6) were built using the function 'lmer' from the lme4 package. Five models were used to test Hypotheses 1, 2, and 3, and two additional models were used to test Hypothesis 4. To test Hypotheses 1–3, 'conflict behavior' was used as the response variable (continuous factor) in each of the five models, and sex (categorical factor with three levels), age (continuous factor), breed (categorical factor with 15 levels, summarized in **Table 1**—for example, Westphalian, Hanoverian, Trakehner, Oldenburger as 'German Warmblood'), performance level (categorical factor with five levels), and type of bit (categorical factor with two levels) as fixed effects. Horse-rider ID was added as a random effect. The factor 'situation' could not be included in the models as it generated an error, likely because the 'education' group was too small for modeling. As a result, this variable was excluded from all models, and its results are presented descriptively.

In Model 0, the above-described variables and fixed effects were included, along with the vertical angle (continuous factor) and the poll angle (continuous factor) as fixed effects. Additionally, an interaction with the shoulder angle (continuous factor) was included to examine the influence of the vertical and the poll angle on conflict behavior. This model represents the complete analysis of all parameters. In Model 1, only the vertical angle was added as a fixed effect to account for influences of this angle on conflict behavior alone. In Model 2, the vertical angle with an interaction with the shoulder angle was used as a fixed effect to test the influence of the height of the head. The third model had the poll angle as a fixed effect to test the impact of the neck angle, and the fourth model had an interaction between the poll angle and the shoulder angle as a fixed effect to isolate the effect of head height on poll angle.

To test our fourth hypothesis, i.e., to determine a cut-off value of the vertical angle at which signs of conflict behavior significantly increase, another two models were built with the same fixed effects as for Model 1, but with the vertical (Model 5) and poll (Model 6) angles transformed into categorical variables. All vertical and poll angles were transformed by grouping the data into four categories of similar size ($n = 48$ or 47) using the function 'cut_number'. For the vertical angle, the following four categories were created: 1) -31.03° to -11.40° ; 2) -11.36° to -7.48° ; 3) -7.47° to -4.05° ; and 4) -3.57° to 10.93° . For the poll angle, these categories were created: 1) 17.60° to 24.58° ; 2) 24.59° to 28.12° ; 3) 28.24° to 31.63° ; 4) 31.73° to 40.12° . The number of categories was chosen to maximize their application of these categories in riding practice. Consequently, Model 5 had the vertical angle as a categorical variable with the four categories as fixed effect, and Model 6 had the poll angle as a categorical variable with the four categories as fixed effect. Sex, age, breed, performance level, and type of bit were added as fixed effects, and horse-rider-ID as a random effect.

All model residuals were inspected for normal distribution using diagnostic Quantile-Quantile Plots (Q-Q Plots) and Kolmogorov-Smirnov tests (all model residuals: $p > 0.05$). An ANOVA (Type I, sequential) was performed to determine p -values for each of the seven models.

3. Results

3.1. Descriptive Statistics

3.1.1. Head and Neck Positions

The distribution of the three measured angles in the sample is shown in **Figure 3**. In total, 178 horses were ridden with their nasal plane behind the vertical, i.e., 63 horses were ridden with a vertical angle between -20° and -10° , while 112 horses were ridden with a vertical angle between -10° and 0° . No horse was ridden precisely at a 0° vertical angle. Only 13 horses were ridden with a vertical angle between 0° and 10° , indicating an HNP with the nasal plane in front of the vertical. Median and interquartile range (IQR) are shown in **Table 3**.

3.1.2. Behavior

The frequencies of conflict behavior (sum of all recorded behaviors) varied from 0 to 362 during three minutes, with a median frequency of 129.17 (IQR: 33.95–224.38; **Figure 4**). The most frequently recorded behaviors were oral behavior (median: 101.7, IQR: 19.22–184.17; **Figure 4B**) and tail swishing (median: 23, IQR: 12.54–58.56; **Figure 4C**). Gait irregularities were observed in 35 horses (total: 61 counts; median: 0, IQR: 0–5), and head shaking was very rarely observed (in 9 horses, total: 12 counts; median: 0, IQR: 0–3). All other behaviors were not observed in this sample (**Table 4**).

3.1.3. Scaling of Behaviors

Figure 5 illustrates the assigned values of both raw behavioral data and scaled data. The linear relationships demonstrate that one count of unusual oral behavior was equivalent to one count of tail swishing, as both behaviors shared the same scaling with a maximum of 180 on the y-axis. In contrast, one count of gait irregularities corresponded to 36 counts (180/5) of tail swishing or oral behavior, as reflected by the y-axis value of 5 for gait irregularities. This scaling allowed for a balanced contribution of different behaviors to the overall analysis.

The prevalence of conflict behavior and the vertical angle in the different situations is shown in **Figure 6**. The smallest vertical angles were measured in the warm-up, followed by competition, and education. For conflict behavior, the order was reversed: the highest frequency was recorded in the warm-up, followed by the competition, with the lowest levels observed in education.

3.1.4. Correlation of HNP Angles

The vertical and poll angles were significantly moderately correlated ($\rho = 0.54$, $p < 0.001$), meaning the smaller the poll angle, the more the nasal plane was behind the vertical. The vertical and the shoulder angles were significantly but weakly correlated ($\rho = -0.34$, $p < 0.001$), indicating that as the head height increased, the vertical angle decreased. This means that the nasal plane was positioned further behind the vertical, i.e., closer to the horse's chest. The poll and the shoulder angles were not correlated ($\rho = 0.11$, $p > 0.05$).

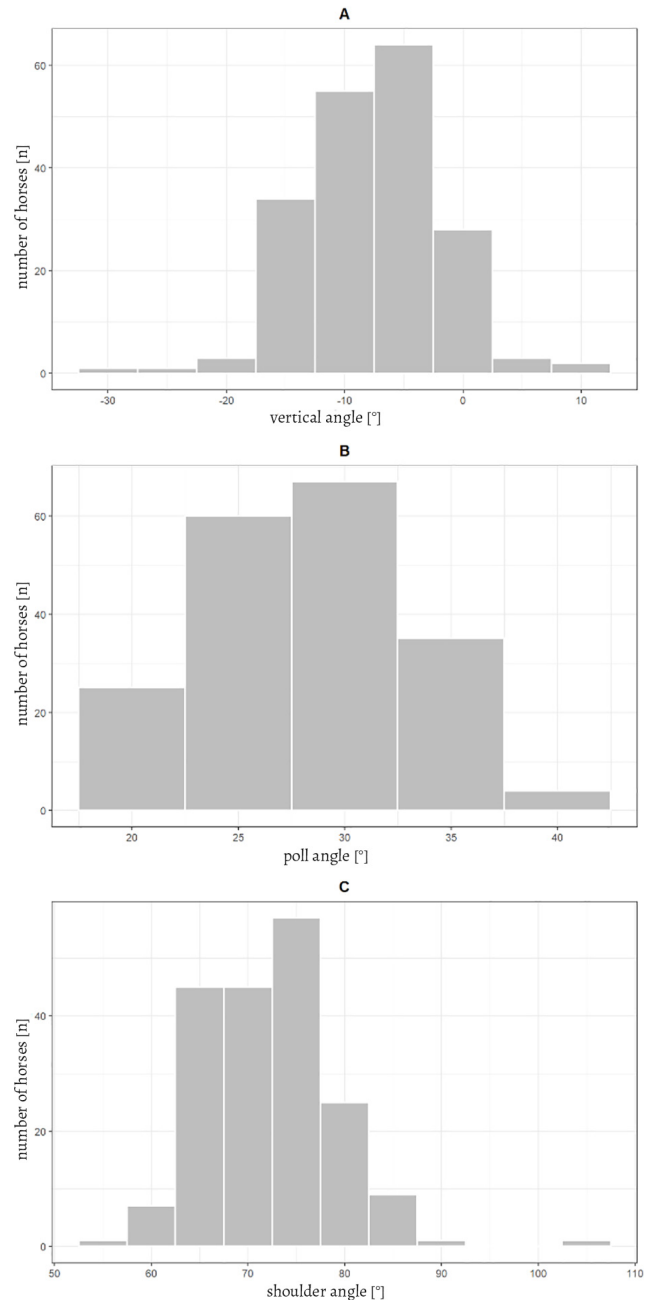


Figure 3: Histograms showing the distribution of the three measured angles across all 191 horses in each situation (warm-up, competition, and education): A) vertical angle, B) poll angle, and C) shoulder angle. The vertical angle reflects the position of the horse's head relative to the vertical plane, with negative values indicating behind-the-vertical positions.

Table 3: Median and interquartile range (IQR) of the three measured angles (in degrees).

Angle	Median [°]	IQR	
		min	max
Vertical angle (α)	-7.48	-15.06	0.10
Poll angle (β)	28.11	21.02	35.21
Shoulder angle (γ)	71.95	62.60	81.30

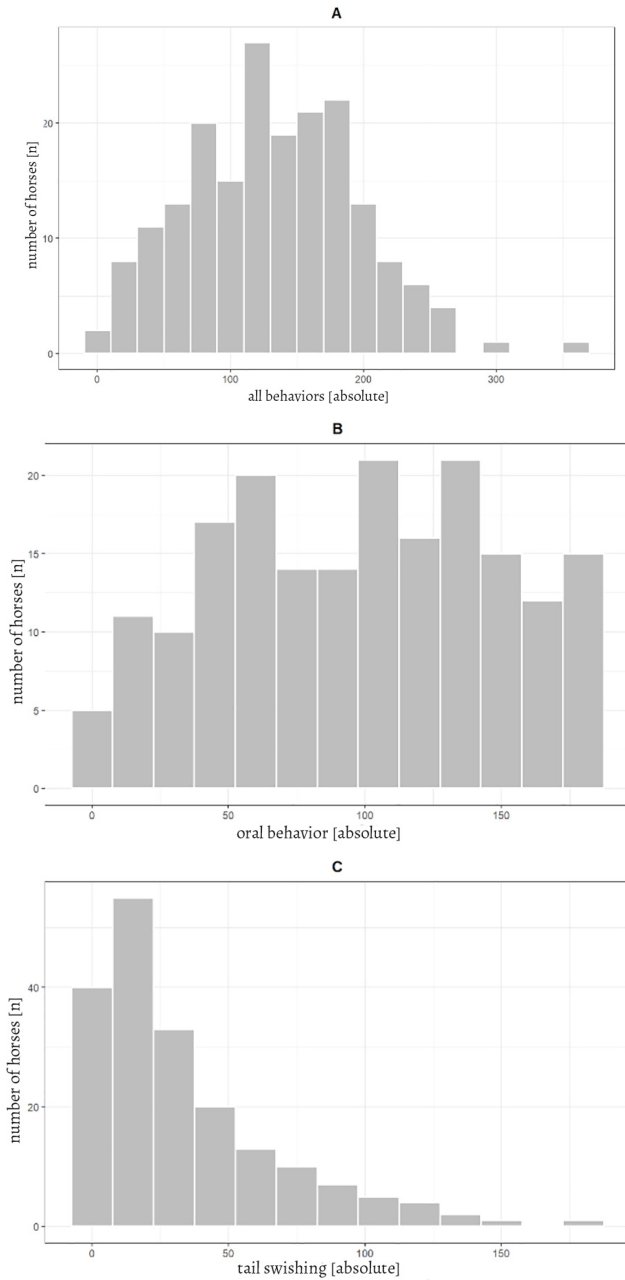


Figure 4: Histograms showing the distribution of conflict behaviors observed in 191 horses across all situations (warm-up, competition, and education): A) all observed behaviors combined into a new category labeled as 'conflict behavior'; B) unusual oral behaviors; and C) tail swishing. The counts represent absolute frequencies per horse.

3.1.5. Correlation of HNP and Conflict Behavior

There was a low negative correlation between the vertical angle and conflict behavior ($\rho = -0.30$, $p < 0.001$; **Figure 7A**). This indicates that the smaller the vertical angle (indicating that the horses were ridden more behind the vertical), the higher the prevalence of conflict behavior. There was also a low negative correlation between the poll angle and conflict behavior ($\rho = -0.38$, $p < 0.001$; **Figure 7B**), indicating that as the poll angle decreased, the prevalence of total conflict behavior increased.

Table 4: Median and interquartile range (IQR) of all behaviors (conflict behavior: unusual oral behavior, tail swishing, gait irregularities, and head shaking) summed over a 3-minute observation period. The latter two behaviors were rarely displayed; therefore, all values are 0.

Behavior	Median	IQR	
		min	max
All behaviors	129.17	33.95	224.38
Tail swishing	23.00	12.50	58.50
Unusual oral behavior	101.70	19.22	184.17
Gait irregularities	0	0	0
Head shaking	0	0	0

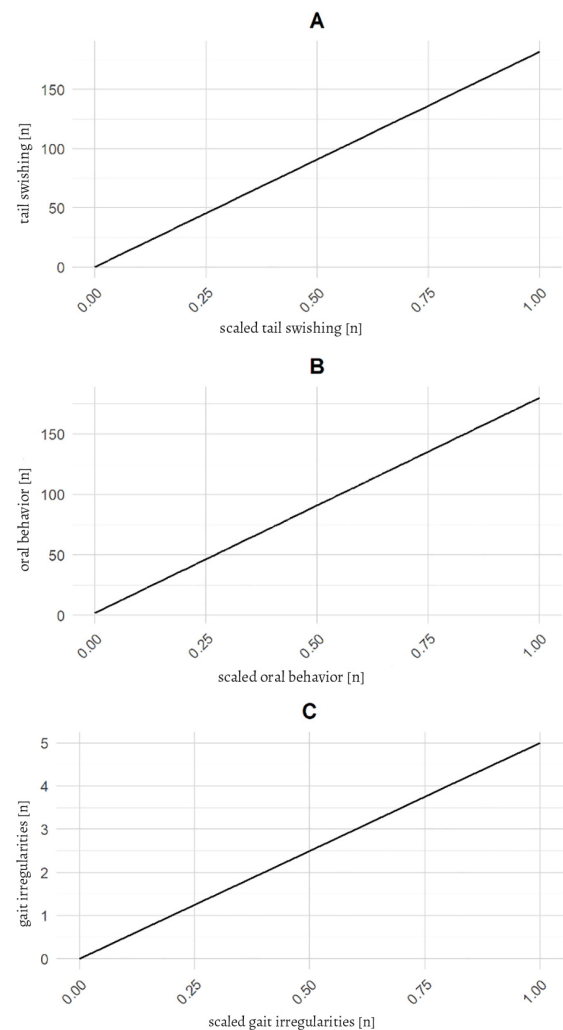


Figure 5: Comparison of raw and scaled behavioral data. A) tail swishing, B) oral behavior, and C) gait irregularities are shown with both raw counts (y-axis) and scaled values (x-axis). For example, tail swishing (A) and unusual oral behavior (B) were roughly equivalent on the y-axis, whereas gait irregularities occurred less frequently compared to the other two variables. For practical application, approximately one count of gait irregularity could be equivalent in value to about 36 counts of tail swishing and/or oral behavior.

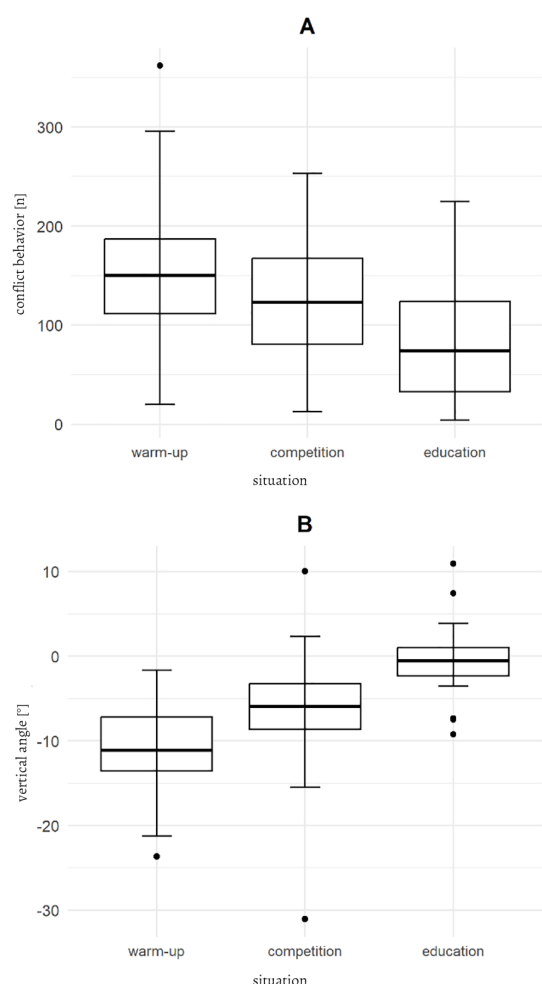


Figure 6: Boxplots showing the effect of the situation (warm-up, competition, and education) on A) the frequency of conflict behaviors (e.g., tail swishing, unusual oral behavior), and B) the vertical angle of the head–neck position (HNP), measured in degrees. Each box represents the interquartile range (IQR), with the horizontal line indicating the median. Whiskers extend to 1.5× IQR, and black dots represent outliers.

3.2. Modeling Results

The results of the linear modeling are shown in **Table 5** for all seven models. All models found a significant effect of sex ($p < 0.01$), with stallions showing more conflict behavior compared to mares and geldings (**Table 5, Figure 8**). Age, breed, and type of bit showed no significant effects on conflict behavior in any of the models.

Model 0, which included all aspects (with the vertical and the poll angle as fixed effects and an interaction of the shoulder), revealed a significant negative effect of the poll angle on conflict behavior ($p < 0.001$), meaning that horses showed more conflict behaviors when the poll angle decreased. The model had a good fit with an AIC of -132.70 and a BIC of -39.52.

Model 1 (with the vertical angle as a fixed effect) had a significant negative effect of the vertical angle on conflict behavior ($p < 0.001$), indicating that horses showed a higher

number of conflict behaviors when the vertical angle decreased. The level of dressage had significant negative effects on conflict behavior for level 3 (M level [medium], $p < 0.05$) and level 5 (A level [beginner], $p < 0.05$), indicating less conflict behavior in lower classes. The model had a good fit, with an AIC of -149.46 and a BIC of -68.71.

Model 2 (with the vertical angle and an interaction of the shoulder angle as a fixed effect) had a significant negative effect of the vertical angle on conflict behavior ($p < 0.001$). Also, there was a significant negative effect of the shoulder angle on conflict behavior ($p = 0.014$). Level 3 ($p < 0.05$) and level 5 ($p < 0.05$) had significant negative effects on conflict behavior, too. The model had a good fit, with an AIC of -137.54 and a BIC of -50.57.

Model 3 found a significant negative effect of the poll angle on conflict behavior ($p < 0.001$), indicating that horses showed more conflict behaviors when the poll angle decreased. The model had a good fit, with an AIC of -168.61 and a BIC of -87.86.

Model 4 detected a significant negative effect of the poll angle on conflict behavior ($p < 0.001$). The model had a good fit, with an AIC of -150.10 and a BIC of -63.13.

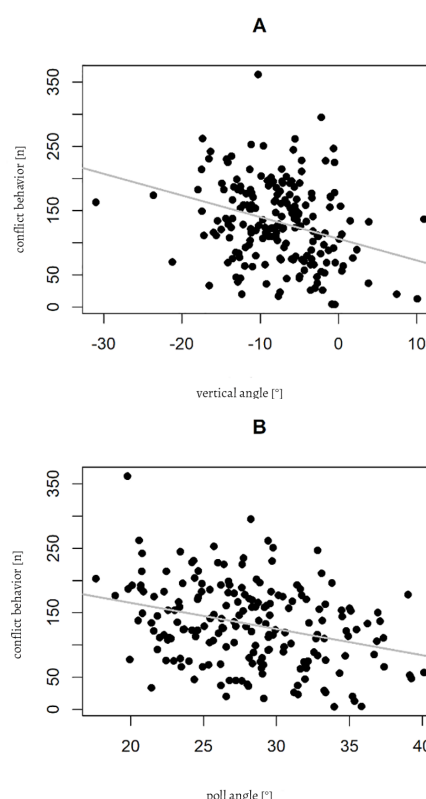


Figure 7: Scatterplots showing the relationship between the angular measurements of head positions and the frequency of conflict behavior in absolute numbers observed in 191 horses across all situations (warm-up, competition, and education). A) Correlation of the vertical angle [°] and conflict behavior ($\rho = -0.30$, $p < 0.0001$), and B) Correlation of the poll angle [°] and conflict behavior ($\rho = -0.38$, $p < 0.0001$). The gray lines represent the linear regression fit for each relationship.

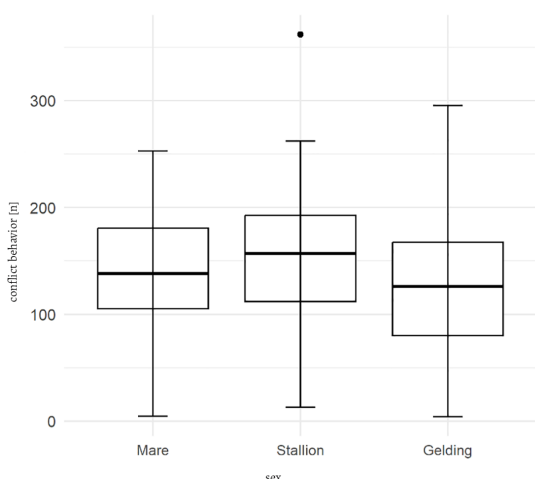


Figure 8: Boxplot showing the total number of conflict behaviors (e.g., tail swishing, unusual oral behavior) in mares, stallions, and geldings. Each box represents the interquartile range (IQR), with the horizontal line indicating the median. Whiskers extend to $1.5 \times$ the IQR, and black dots indicate outliers. Stallions exhibited significantly more conflict behaviors than mares ($p < 0.01$, results from lmer and ANOVA). No significant difference was observed between mares and geldings.

Overall, all models exhibited similar significant effects, indicating the importance of certain variables such as the vertical angle (Models 1 and 2), the poll angle (Models 0, 3, and 4), and the sex of the horses (all models, **Figure 8**) in predicting conflict behavior. Model 0 showed a slightly better fit, based on AIC and BIC values, compared to the other models. The non-significant effects of age, breed, and type of bit used remained consistent across all models.

When transforming the vertical angle and the poll angle into categorical variables and incorporating these into Model 5 (vertical angle) and 6 (poll angle), it was found that horses displayed more conflict behaviors starting at a vertical angle of -7.5° and lower (**Figure 9**), and at a poll angle of 24.5° and lower. Stallions were again connected with showing more conflict behavior ($p < 0.05$). Sex, age, breed, performance level, and bit had no effect on conflict behavior. Model 5 had an AIC of -131.93 and a BIC of -44.97 . Model 6 had an AIC of -146.37 and a BIC of -59.40 .

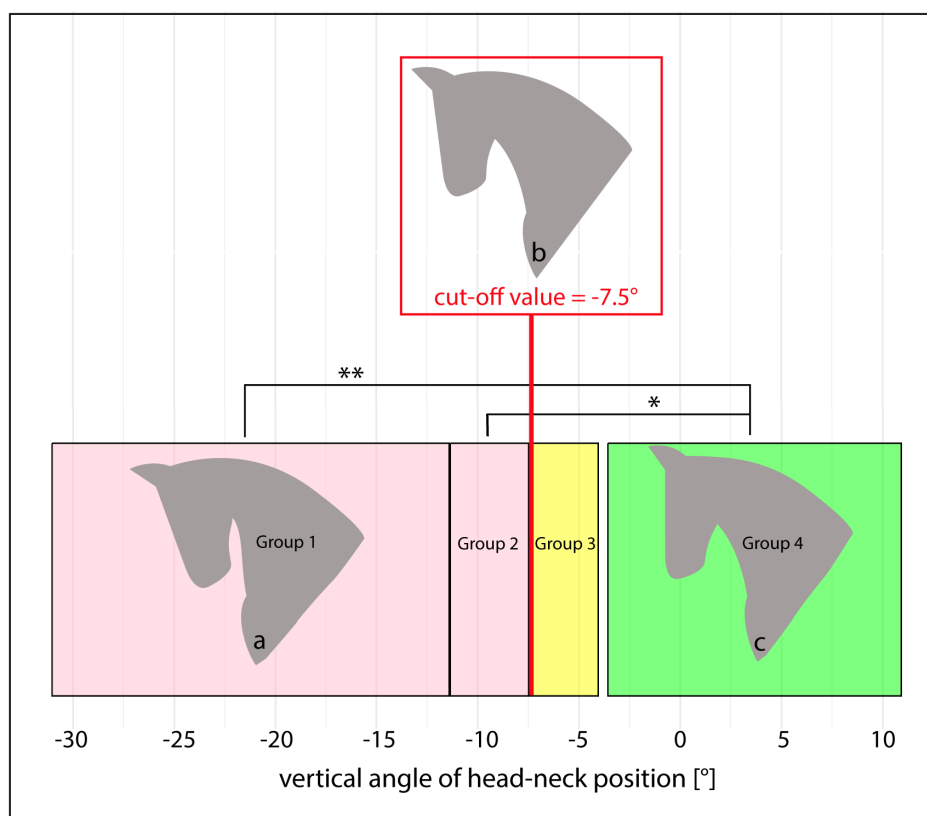


Figure 9: Results of Model 5 (vertical angle as a categorical variable with 4 groups) and subsequent ANOVA. Group 1: -31.03 to -11.4° ; Group 2: -11.36 to -7.48° ; Group 3: -7.47° to -4.05° ; Group 4: -3.57° to 10.93° . Groups 1 and 2 are significantly different from group 4, with no other significant differences detected. Significance levels: *** $p = 0$, ** $p = 0.001$, * $p = 0.05$. Colors indicate the authors' suggestions for practical implication with the green zone (group 4) connected to low conflict behavior, yellow (group 3) to intermediate conflict behavior, and red (groups 3 and 4) with the highest conflict behavior in relation to the HNP position. (a) Shows a vertical angle of -20° , (b) a vertical angle of -7.5° representing the recommended limit of flexion, and (c) shows a vertical angle of 0° .

Table 5: Results of Models 0–6 (lmer). All models had conflict behavior as the response variable, with sex, age, breed, performance level (A, L, M, S), and type of bit as fixed effects, and horse-rider-ID as a random effect. Model 0 was the complete model and included the vertical angle (continuous factor) and the poll angle (continuous factor) as fixed effects. Additionally, an interaction with the shoulder angle (continuous factor) was included. Model 1 had the vertical angle as a fixed effect; Model 2 included an interaction between the vertical angle and the shoulder angle; Model 3 included the poll angle; and Model 4 included the poll angle with an interaction with the shoulder angle. Models 5 and 6 both had conflict behavior as the response variable, with sex, age, breed, performance level, and type of bit as fixed effects and horse-rider-ID as a random effect. Model 5 had the vertical angle as a categorical variable with four categories as a fixed effect, and Model 6 had the poll angle as a categorical variable with four categories as a fixed effect. Only significant factors are shown. Sex 'gelding' and performance level 'Grand Prix Special' were the intercepts in all models, respectively.

Model	Term	Estimate	Std. Error	t-value	df	p-value
Model 0	(Intercept)	0.256	0.078	3.291	59.317	0.001
	Vertical angle	-0.018	0.013	-1.328	130.329	0.185
	Poll angle	-0.049	0.013	-3.798	136.999	0.000
	Shoulder angle	-0.012	0.011	-1.136	131.790	0.258
	Mare	0.059	0.029	2.067	70.399	0.040
	Stallion	0.074	0.023	3.273	73.164	0.001
Model 1	(Intercept)	0.285	0.076	3.772	58.635	0.000
	Vertical angle	-0.034	0.009	-3.691	139.640	0.000
	Mare	0.054	0.028	1.919	70.415	0.059
	Stallion	0.074	0.023	3.275	75.759	0.002
	Level S	-0.035	0.041	-0.847	106.978	0.399
	Level M	-0.113	0.055	-2.060	97.878	0.042
	Level L	-0.063	0.079	-0.804	93.016	0.423
	Level A	-0.165	0.077	-2.152	83.900	0.034
Model 2	(Intercept)	0.285	0.076	3.772	58.635	0.000
	Vertical angle	-0.034	0.009	-3.691	139.640	0.000
	Mare	0.054	0.028	1.919	70.415	0.059
	Stallion	0.074	0.023	3.275	75.759	0.002
	Level S	-0.035	0.041	-0.847	106.978	0.399
	Level M	-0.113	0.055	-2.060	97.878	0.042
	Level L	-0.063	0.079	-0.804	93.016	0.423
	Level A	-0.165	0.077	-2.152	83.900	0.034
Model 3	(Intercept)	0.250	0.078	3.215	60.811	0.002
	Vertical angle	-0.051	0.011	-4.854	125.246	0.000
	Shoulder angle	-0.026	0.010	-2.479	136.607	0.014
	Mare	0.057	0.029	1.966	72.671	0.053
	Stallion	0.077	0.023	3.388	75.690	0.001
Model 4	(Intercept)	0.270	0.076	3.564	59.326	0.001
	Poll angle	-0.059	0.010	-6.064	137.275	0.000
	Shoulder angle	-0.002	0.008	-0.248	138.964	0.805
	Mare	0.063	0.028	2.268	69.592	0.026
	Stallion	0.071	0.022	3.221	73.516	0.002

Model	Term	Estimate	Std. Error	t-value	df	p-value
Model 5	(Intercept)	0.321	0.080	4.033	56.038	0.000
	Vertical.Class1-2	-0.029	0.022	-1.306	121.645	0.194
	Vertical.Class1-3	-0.050	0.024	-2.038	137.591	0.043
	Vertical.Class1-4	-0.099	0.027	-3.635	136.032	0.000
	Mare	0.057	0.029	1.929	66.773	0.058
	Stallion	0.075	0.023	3.203	73.768	0.002
Model 6	(Intercept)	0.348	0.080	4.376	60.709	0.000
	Poll.Class1-2	-0.083	0.022	-3.752	136.450	0.000
	Poll.Class1-3	-0.109	0.022	-4.858	127.397	0.000
	Poll.Class1-4	-0.135	0.028	-4.896	135.174	0.000
	Mare	0.056	0.029	1.922	69.740	0.059
	Stallion	0.066	0.023	2.877	75.345	0.005

4. Discussion

This study explored the full range of head–neck positions (HNPs) used in dressage horses during warm-up, competition, and educational situations to assess their impact on equine welfare, as indicated by conflict behaviors. It aimed to identify critical angles associated with welfare risks to provide evidence-based guidance for riders, judges, and other stakeholders in evaluating training and competition practices.

Our first hypothesis proposed that the degree of flexion would influence behavioral parameters, particularly conflict behaviors. The data fully supported this hypothesis. A greater degree of ventral head flexion was associated with a higher total frequency of conflict behaviors. Although the correlation coefficient values for head angle and conflict behavior were moderate ($r = -0.3$ for the vertical angle and $r = -0.38$ for the poll angle), it was statistically significant, indicating a meaningful association between HNP and conflict behavior. However, the moderate strength of the correlations also suggests that HNP is not the sole explanatory variable. Other factors not captured in this study may also contribute to the occurrence of conflict behaviors. The horse–rider system is inherently multifactorial, influenced by aspects such as training methods, rider skill, saddle fit, and individual horse temperament. Nevertheless, our data highlight HNP as one of the key factors that should be considered when aiming to improve equine welfare. The predominant manifestations of conflict behavior comprised unusual oral behavior and tail swishing. Gait irregularities and head shaking were shown less frequently.

Tail swishing, noted as one of the prevailing behaviors in competition horses, has been consistently documented across various studies [20,22,26,33,50,51]. Yet, investigations into the influence of different HNPs on the movements of the tail have yielded disparate findings. While some studies have reported significant variations in the frequencies of tail swishing based on HNP categories [8,38,50], others have not [33]. Despite this, frequent tail swishing is widely regarded as an undesirable behavior during riding, as emphasized in previous research [8,26,33,38]. This behavior is often associated with discomfort,

irritation, or stress, making it a relevant welfare indicator. In line with this, major equestrian governing bodies, including the FEI [52], the German Equestrian Federation [13], and Swiss Equestrian [15], categorize excessive tail swishing as a reason to downgrade performance in competition. The German Equestrian Federation particularly emphasizes that a relaxed and slightly swinging tail indicates suppleness and relaxation during riding [53]. The frequent tail swishing observed in our study aligns with these standards, indicating that horses were displaying undesirable behavior as recognized by both equestrian federations and researchers.

Along with the frequent tail swishing, an increase in unusual oral behavior was also observed. Again, rulebooks explicitly require a horse "chewing the bit with a quiet, sensitive mouth" during riding [52]. Yet, research has shown that these conflict behaviors are very common [8,11,22,26,36]. Deviations from a closed mouth, such as chewing with an open mouth, sticking the tongue out, or 'flapping' the lips, are interpreted as signs of discomfort, stress, and/or pain [54,55]. Considering that nearly 10% [4] and 45% [7] of Danish competition horses, and 52% of Finnish event horses [5] examined after competitions had mouth lesions, it is reasonable to expect that some of these ridden horses may exhibit signs of pain and/or discomfort. Moreover, the increased occurrence of oral behavior during transitions, as reported in another study, may be linked to heightened rein contact [9], potentially offering a plausible explanation for oral lesions observed in some horses. However, further research is needed to confirm this association, as other factors may also contribute to the development of such lesions. Additionally, a recent study proposed that oral 'defensive' behavior can also serve a functional role: horses may learn, through trial and error, to use specific mouth movements to reduce aversive stimuli such as rein tension [55].

The findings from our study suggest that oral behavior is also directly related to HNP, whereas tail swishing, when examined in isolation, does not necessarily correlate with HNP [22]. Instead, tail swishing is more likely linked to other aversive stimuli, such as those from the rider or equipment, like spurs [22,26,56].

Our second hypothesis proposed that a smaller poll angle would have a more restrictive impact on the horses' conflict behavior and, consequently, their welfare compared to the vertical angle. When analyzed separately, both the vertical angle and the poll angle significantly influenced conflict behavior. However, when both angles were analyzed together in one model, the influence of the poll angle became more prominent, overshadowing the effect of the vertical angle. This suggests that the poll angle has a greater influence on the horses' behavior compared to the vertical angle. This may be attributable to the direct correlation between a tight poll angle and restrictions of the laryngopharyngeal system, i.e., the anatomical structures involved in the upper respiratory tract that play a critical role in breathing, swallowing, and vocalization. Several studies found a decrease in pharyngeal diameter with increased neck flexion [36,39,40,42]. This finding supports our observation that the poll angle had a stronger impact on conflict behavior, which, in turn, has more profound consequences for the horse's overall welfare. However, under field conditions, the poll angle is practically undetectable during live scoring, as the naked eye of any observer lacks reliable reference points to estimate a reasonably accurate angle. This is not the case for the vertical angle. Vertical lines are common in the riding environment, such as fence posts, walls, lampposts, or doors, all of which can serve as reference lines for assessing the vertical angle of the horse's nasal plane. This makes it easier for observers, such as stewards, judges, or riders, to gauge alignment and posture in relation to these fixed points. In a field study without video recordings [8], as well as in standardized experimental studies [36,57], horses with a vertical angle of -10° were categorized as being consistently behind the vertical. Horses with vertical angles between 0 and -10° were classified as borderline cases [8]. The vertical angle is well established as a reference in equestrian regulations and continues to be recommended for this purpose. Once precise measurements are available, the current study also advocates for the documentation of the poll angle, as it appears to have a more detrimental impact on the horse.

Our third hypothesis focused on the influence of the height of the head on the occurrence of conflict behavior. This factor is represented by the shoulder angle, measured between the poll, shoulder, and withers (**Figure 1**). Our results showed that the higher the head was held, the smaller the angle of the shoulder and neck. No interaction of the vertical or poll angle with the shoulder angle was found in any model. Instead, in model 2, there was a significant negative influence of the shoulder angle on conflict behavior, meaning the smaller the shoulder angle and, therefore, the higher the head was held, the higher the prevalence of conflict behavior.

Surprisingly, the poll angle had no such influence on the shoulder angle. Given that the poll angle influenced behavior more than the position of the nasal plane (Model 0), an increase in conflict behavior with a higher head was expected. Yet, the results make sense insofar as a tight poll angle is detrimental in any case, regardless of head height, unlike the vertical angle. A small vertical angle (e.g., -20° , **Figure 1B**) automatically results in a smaller poll angle (e.g., -5°) with a high head, while the same vertical angle with a low head leaves more space for the lower neck structures. In summary, across all seven models, the shoulder angle

had no significant influence on conflict behavior. Therefore, smaller head angles appeared to increase conflict behavior, regardless of head height, with a tendency for conflict behavior to increase with a higher neck position (a smaller shoulder angle).

Our fourth hypothesis aimed to define a cut-off value for flexion, beyond which the horse's conflict behavior is significantly negatively affected by the degree of flexion. Defining this value is essential for practical applications of existing laws [45] and competition rules [13,52]. Current recommendations are limited to the requirement for the position of the nasal plane to be at or slightly in front of the vertical [13–15].

An important consideration is how angle specifications are interpreted across different regulatory standards. Terms such as "slightly" (in front of the vertical) or "extreme" (flexions) can vary widely in meaning, depending on individual perspectives shaped by personal experiences, riding knowledge, and ethical considerations. It is imperative that more precise definitions are developed and standardized to allow for greater objectivity, thereby enhancing validity and consistency. Relevant federations are encouraged to address this issue, as doing so would minimize future debates and increase transparency for all stakeholders.

To our knowledge, only Switzerland currently has regulations regarding the use of specific HNPs. Since 2014, rollkur has been prohibited by law: "Additionally, prohibited for equines are [...] methods that induce hyperflexion of the equine neck or back (Rollkur) [45]." Nevertheless, no sanctions related to this regulation have been officially recorded since its implementation [15], despite the results of this study suggesting that the prevalence of riding with the nasal plane behind the vertical in Switzerland may be comparable to levels observed internationally, where no such law exists. Obviously, implementing this law has proven difficult, as the definition "Attributes of Rollkur, an especially in dressage riding used method of Hyperflexion (overbending), are a particularly deep head-neck position and an overstretched back, forced through violent interaction of the rider's hands and/or through equipment" [46] leaves room for interpretation, particularly regarding what constitutes a 'deep' position. Attributes such as 'particularly deep' and 'violent interaction' are subjective descriptions prone to individual interpretation.

To investigate a potential limit for HNP from a scientific perspective, two additional models (Model 5 and Model 6) were included in the analyses, transforming the continuous variable of the vertical angle into a categorical variable. This categorization divided all measured vertical angles into four equally sized groups based on the number of rides in each category to assess their impact on conflict behavior. The ANOVA results revealed a significant difference between groups 1 and 2 compared to group 4, but not to group 3, with groups 1 and 2 ranging in vertical angles from -31° to -7.5° . Based on these findings, a 'traffic light' system is proposed to categorize the different HNP: green zone (group 4) connected to low conflict behavior, yellow or amber zone (group 3) associated with intermediate conflict behavior, and red zone (groups 2 and 1) indicating the highest amount of conflict behavior in relation to head position. As a result

of our analysis, a vertical angle of -7.5° is suggested as the absolute limit of tolerated flexion for safeguarding horse welfare while riding. Group 2, ranging from -7.47° to -4° , is recommended as a yellow zone, with no significant differences observed compared to other groups. However, closely monitoring horse-rider pairs is advised within this range, and observing the horses' behavior is essential to ensure their well-being, as riding with a nasal plane behind the vertical poses a risk to animal welfare [12]. It appears that the transitions from flexion that raise welfare concerns to only mild discomfort related to neck flexion occur in group 2. All vertical angles greater than -4° would be categorized within the green zone, indicating minimal conflict behavior and a lower risk to welfare.

The result of a limit of -7.5° fits reasonably well into the existing literature [8], showing significant differences in conflict behavior in ridden horses with a nasal plane more than 10° behind the vertical compared to all other positions. Additionally, a correlation was found that horses ridden with their nasal planes at a vertical angle of -10° behind the vertical showed significantly more conflict behavior compared to horses ridden 5° in front of the vertical [36]. In addition, a meta-analysis confirmed the vertical angle as a valid threshold, with positions of the nasal plane behind the vertical being correlated with stress and/or pain in most studies investigating the influence of head flexion on horses [12]. Both national and international rulebooks, as well as current scientific literature, widely support the recommendation that the nasal plane should be at (or in front of) the vertical. However, based on the results of our study, this widely acknowledged standard is problematic: a majority of horse-rider pairs would face sanctions if the strict vertical angle of 0° , as outlined in all competition rules, were enforced. To enable the practical application of sanctions in a reasonable manner, a more realistic limit of -7.5° behind the vertical is proposed in this study, which better reflects current riding practices.

An important factor to consider is the duration of neck flexion necessary to impair equine welfare. In our study, each measurement was taken over a 3-minute period, and the average HNP values were analyzed. Our data clearly indicate that just three minutes of neck flexion with vertical angles greater than -7.5° behind the vertical has a detrimental effect on horse welfare, as evidenced by a significant increase in conflict behaviors in these positions. Unfortunately, shorter durations were not assessed statistically in this study. However, it is reasonable to hypothesize that neck flexions beyond the vertical may cause discomfort regardless of duration, potentially inducing adverse effects even in the short term. Supporting this assumption, a study on the muscle activity of the flexing neck muscles demonstrated an abnormal activation pattern as soon as the nasal plane was held behind the vertical, both in ridden and unriden horses [58]. Additionally, none of the studies included in a recent meta-analysis on the effects of hyperflexion suggested that the duration of neck flexion is a relevant factor in determining its impact. Riding with the nasal plane behind the vertical was shown to have a negative impact on horse welfare, regardless of how long it was maintained [12]. From a scientific perspective, it is recommended that warnings be issued promptly after neck flexion exceeds a

-7.5° vertical angle to encourage posture adjustments. To safeguard equine welfare, it is recommended that if this position is maintained for approximately three minutes or longer, whether continuously or cumulatively, appropriate sanctions should be considered. Given the potential welfare implications, a precautionary approach is advisable. In line with the principle of "better safe than sorry," the establishment of clear regulatory guidelines would help ensure responsible riding practices.

A question emerging from our results is the lack of explanation for the high incidence of positions with the nasal plane behind the vertical. Of the 191 horses observed, 178 (93%) were ridden with a vertical angle lower than 0° , and 132 horses (69%) had a vertical angle lower than -5° behind the vertical. 96 horses (50.3%) had a vertical angle lower than -7.5° behind the vertical. Consequently, riding with a negative vertical angle seems to be the current standard at competitions, at least in elite classes. In our sample, two models showed an effect associated with the lower competition classes, where a reduced prevalence of conflict behavior was observed. This is supported by another study [8], which found that competition level significantly influenced conflict behavior; i.e., the higher the level, the greater the prevalence of conflict behavior. Interestingly, in that study, a nasal plane behind the vertical was partly penalized by the judges in lower classes but not in higher classes. In contrast, a positive correlation was found between high scores and a nasal plane behind the vertical in elite classes [22]. A similar finding was reported in another study focusing on piaffe movements [19]. The absence of correlations between low scores and hyperflexed positions may indicate a failure in the application of competition rules.

Research has shown that attitudes and knowledge acquisition in sports can be significantly influenced by the behavior of elite athletes, as indicated by studies on observational learning (e.g., [59,60]). Consequently, leisure riders and riders competing at lower levels may look up to elite riders as role models, potentially adopting similar techniques and practices. This highlights the importance of fostering positive role models to promote better practices across all riders. Addressing this inconsistency is proposed to enhance equine welfare at all levels of the sport, ultimately setting the standard for good riding within the broader equestrian community. Notably, while sanctioning riding behind the vertical may discourage undesirable postures, it does not support riders in adopting better alternatives. For meaningful and lasting improvements in equine welfare, it is important to support and educate riders, i.e., raising awareness of the impact of different head–neck positions on horse welfare and promoting training approaches that encourage a more open frame. A combination of education and regulation is likely to be most effective in achieving sustainable improvements in riding practices.

5. Limitations

One limitation of our study is the composition of the sample of ridden horses. To accurately investigate a parameter such as neck flexion and establish appropriate cut-off values for acceptability, it is essential to assess the full range of its manifestations, which typically follow a Gaussian distribution. Failing to consider the entire range

of the parameter could result in incomplete or inaccurate conclusions about the appropriate cut-off values. Since most of the measured angles reflected a nasal line behind the vertical, with only a few exceptions, the defined cut-off value of -7.5° likely limits its accuracy. The focus on this narrower range of angles may have skewed the value too far to the left on the x-axis, resulting in smaller cut-off values than might be representative of the full range of head-neck positions. In this case, all degrees of the vertical angle of a ridden horse from -25° up to 25° should have been included in the sample. However, in a field study, the sample is heavily influenced by real-world conditions. Here, the Gaussian distribution exhibited a shift, with the peak not at the expected maximum of approximately 0° , but around -10° . Thus, the defined cut-off angle is likely smaller than it should be. Including more instances where the nasal plane was in front of the vertical would likely have produced a larger cut-off, potentially closer to vertical. This suggests that the current value might underestimate the true impact on the occurrence of conflict behaviors shown by the horse. This may have led to a misrepresentation of angles greater than 0° , as only a small number (13 out of 191 horses, or 6.8% of the sample) were ridden with their nasal plane in front of the vertical. Therefore, the cut-off value should not be regarded as an ideal standard but rather as a pragmatic threshold reflecting current riding practices, which often deviate from generally accepted guidelines. Recognizing this, promoting incremental, achievable adjustments can serve as practical steps toward aligning everyday practices with welfare-oriented standards.

Another potential limitation of our study might be the impossibility of selecting representative portions for the entire warm-up process, as it was not performed in a standardized way. The ridden program in the warm-up was freely chosen by the riders. This limitation was addressed by selecting the same warm-up phase for each rider (the beginning of the working phase), which nonetheless may not be fully representative of the whole warm-up process for each individual rider-horse pair. However, similar approaches have been used in other studies assessing warm-up situations [8,61].

Our HNP analysis measured HNPs across all available single frames captured in profile view. Previous studies have typically analyzed only a few frames to estimate HNPs [33,58,62] or relied solely on qualitative analysis, which is prone to subjectivity [8,9,20,26,38,63]. Our HNP assessment covered the entire video footage, providing the most accurate estimation possible in accordance with our methodology, which involved filming from outside the riding area, as described previously [22]. A total of approximately 13,500 frames were manually annotated and subsequently analyzed, evenly distributed across the sequences to minimize variations related to gait. However, the number of frames acquired for each sequence varied depending on the number of profile views captured for each rider. This limitation must be considered, especially in warm-up areas and educational rides, where only one camera was used.

The competition footage was captured by a professional service with multiple cameras, resulting in a substantially larger number of profile views. There, the best views were

selected in a standardized manner for each ride, enhancing the precision of competition data analysis. Yet, achieving the highest level of accuracy would require continuous angle detection, which is only possible by filming from the center of the arena to ensure complete independence from variations in gait and perspective. Unfortunately, this is not feasible in a field setting. Moreover, attaching sensors to horses during field studies to consistently measure HNPs directly as a gold standard, especially in official competitions, is not yet permitted. Nevertheless, future advancements in regulations and technology may enable the implementation of such methods, for example, using AI-based 3D modeling or similar approaches.

6. Conclusions

The present study provides valuable insights into riding practices during warm-up, competition, and education in national and international dressage. Our findings support the hypothesis that increased neck flexion is associated with a higher frequency of conflict behaviors, such as tail swishing and oral behavior, both of which are considered undesirable according to equestrian rulebooks. Furthermore, the study highlights the significant influence of the poll angle, suggesting it plays a more prominent role in inducing discomfort than the more commonly discussed position of the nasal plane. This study also proposes a cut-off of the nasal plane at -7.5° behind the vertical as a practical limit for ensuring equine welfare, balancing scientific findings with current riding practices.

The high prevalence of negative vertical angles observed in competitions raises concerns about current standards. To enhance equine welfare and maintain the sport's social license to operate, stricter enforcement of regulations on head and neck positions is urgently needed in both competition and warm-up areas. While sanctions may reduce harmful postures, lasting welfare improvements require education—promoting more open head-neck positions alongside regulation. Future technological advancements, such as continuous angle detection through sensor-based systems or AI-driven computer vision techniques, may enhance the accuracy and enforcement of these standards.

Authors' Contributions

K. Kienapfel: Conceptualization, Methodology, Validation, Formal Analysis, Investigation, Resources, Data Curation, Writing - Original Draft, Writing - Review & Editing, Visualization, Supervision, Project Administration, Funding Acquisition. E. Hartmann: Writing - Original Draft, Writing - Review & Editing, Visualization. B. Preiss: Validation, Formal Analysis, Writing - Original Draft, Visualization. I. Bachmann: Conceptualization, Resources, Writing - Original Draft, Writing - Review & Editing, Supervision, Funding Acquisition.

Data Availability

The authors confirm that all data underlying the findings are fully 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

This type of non-invasive behavioral research is approved under the German Animal Protection Act and does not require study-specific permission. The researchers did not interfere in any way with the riding, horses, or riders, and all riding corresponded to the routine competition procedures. No additional actions were undertaken for this study. Data collection was based on the analysis of HNP and horse behavior from video footage obtained from horse-rider pairs. Filming was carried out in publicly accessible areas, ensuring no disruption to the competition environment. No direct interaction with riders or interference in warm-up activities occurred. Where required, permission to film was obtained from the event organizers in accordance with competition regulations and ethical guidelines. In addition, the authors confirm that the study has followed the guidelines of the Declaration of Helsinki. The data were anonymized for both riders and horses.

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Conditionality in the Equestrian World: A Preliminary Approach

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Abstract

The theory of conditionality originates from the field of social thinking, specifically from the study of normative aspects that are considered conditional. It examines legitimate transgressions and has numerous applications, particularly in road safety. The originality of this study lies in applying this theory to the equestrian world to highlight "normative latitudes" and the risks associated with the human-horse relationship. The main tool used was a Conditional Scripts Questionnaire (CSQ), based on scenarios and situations adapted to the equestrian world. This tool consisted of 7 scenarios: riding helmet, protective vest, riding boots, riding pants, snaffle bridle, protective horse boots, and safety rules. In each scenario, several conditional situations were evaluated, such as "The equine partner belongs to a riding club." A link to an online questionnaire was completed by 46 riders recruited using the snowball sampling technique. The results of the CSQ, analyzed through chi-square testing and quartile analysis, revealed a significant difference in the ordinal distribution of the seven scenarios when considered collectively. The scenario with the lowest conditionality was wearing riding pants, while the scenario with the highest conditionality was the use of a protective vest. Although each scenario varied in its level of conditionality, the degree of intra-scenario conditionality remained consistent across all situations. Additional measures related to risk perception suggested that certain contexts, such as riding one's horse, tended to increase conditionality.

Keywords

Equine psychology; human-horse relationship; animal welfare; theory of conditionality; Conditional Scripts Questionnaire; safety prevention

1. Introduction

The theory of conditionality, developed from fundamental and applied research on the peripheral aspects of social representations [1], aims to demonstrate that any system of rules is negotiable. It shows that the social rule reflecting actual practices can be more or less distant from the legal rule. The more the legal rule is subject to debate, the more conditionality is observed. This theory, used to explain the risks involved in mobility, particularly in driving behavior, refers to "calculated risk-taking" [2].

The particularity of the equestrian world relates to issues concerning safety and health for both the rider and the horse. As in driving, the equestrian world faces numerous injuries and fatalities [3]. According to the Brain Injury Association of Missouri [4], horseback riding is a more dangerous activity than skiing and motorcycling. In 2023, 74.83% of horse-related deaths were caused by head and neck injuries, and the main causes of riding injuries (83.4%) were falls from the horse. Research indicates that the well-being of horses and human safety are interconnected [5]. Horses are managed by humans and are sensitive to human behavior [6,7].

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These elements lead us to question the issue of conditionality concerning the practice of horseback riding, given that the uniqueness of this activity lies in the relationship between humans and horses.

2. Theoretical Framework

The theory of conditionality falls under the field of social representations [8–14]. Research initiated on normative aspects within the field of social thinking [15] led to the development of the theory of conditionality [2], particularly in its application to road safety. This theory advocates for the role of normative latitudes within the system and the existence of shared conditionality [2,16].

A good illustration of this theory can be found in the field of road safety. To study these legitimate transgressions, the Conditional Scripts Questionnaire (CSQ) was developed [16], working from the concept of "script" [17], based on scenarios (for example, speed limits or red lights) and circumstantial situations that can justify transgressions (for example, not respecting the speed limit when going to work). These studies revealed the existence of two normative systems: the system of social norms and the system of legal norms (the Highway Code). While the speed limit appears to be the most conditional scenario, with a significant gap between the two systems, at the other extreme, wearing a seatbelt is the least conditional. In this case: "The fact that the drivers find no circumstance to justify not wearing the seat belt (in the front) attests to the integration of a formal rule in the representation" [2].

As conditionality defines legitimate transgressions within representations, it could quite easily be compared to "calculated risk-taking." The objective of revealing conditionality is not to identify groups who commit violations, as the author wrote: "The aim of the research described in this paper is not to identify the groups which commit violations nor the types of drivers who are potentially dangerous, but to study the representation of driving using a normative approach" [16].

Conditionality has also been studied with pedestrians [18] and motorcyclists [19,20]. Additionally, conditionality has been examined alongside other theoretical frameworks, such as the locus of control [21] and decision-making theory [22]. While most research based on the theory of conditionality and the Conditional Scripts Questionnaire has been conducted in the field of road safety, other areas, such as agriculture [23] or tanning behavior in China [24], have also been explored.

The human-horse relationship has a long history and spans across the ages. There is a connection between these two entities that encompasses both respect and trust [25]. Over the years, this relationship has evolved, from one of predation to one of collaboration (war, farming, etc.), and later to one of artistic and sporting pursuits (leisure, artistic performances, circuses, equestrian competitions, etc.) [26]. As it is written: "...horses became progressively important 'tools' for transportation and, like other domestic animals, they are currently more and more used as companion animals [27,28]." Horses are social beings, capable of sensing

human emotions [7,29]. It is important to foster a positive relationship with horses, as understanding these aspects can help improve their well-being [30]. Several factors, such as diet, stables, social contact, and training methods, must be considered in the human-horse relationship. The term "relationship" refers to a series of interactions with a particular partner, for whom we develop expectations for future interactions, whether positive or negative. Therefore, it is essential to balance "negative" interactions to minimize their impact on the relationship with the horse. As a result, the risk of accidents can be reduced by increasing the number of interactions with one's equine partner, and establishing a relationship of trust is essential [31,32]. Additionally, many studies have shown that interactions with horses have a positive effect on humans' emotional and physical well-being [33,34]. The relationship established between humans and horses can facilitate the expression of emotions, motivate people to change, and foster bonds [35]. Equipment is also important to maintain contact with the animal or to protect against injury (e.g., snaffle bridle, protective horse boots).

Horseback riding is considered a dangerous activity (listed among the top 10 most dangerous sports) due to the potential consequences and injuries that can result from a fall [36,37]. When it comes to human-horse relationships, accidents and incidents involving horses affect both professionals and non-professionals alike [28]. Some studies have indicated that accidents, especially those involving kicks, are more related to the frequency and intensity of interactions with horses rather than the level of skill. For example, the authors wrote: "risk of serious injury appears to be a function of cumulative exposure to horses, not level of expertise. Experience is not protective; helmets are" [38]. In the same vein, it has been suggested that the risk of serious injury depends more on how often someone is around horses than on how experienced the rider is [39].

The present study distinguishes between short interactions, whether with a familiar or unfamiliar horse (e.g., a veterinarian), and long-term relationships (e.g., an owner). This study aims to analyze equestrian conditionality to better understand and prevent risks, as well as to improve equine welfare.

General Hypothesis 1 - The use of safety equipment in horseback riding depends on the circumstances.

- H1 - Wearing a riding helmet is conditional.
- H2 - Wearing a safety vest is conditional.

General Hypothesis 2 - The use of equipment to improve comfort (for the rider or the horse) when riding depends on the circumstances.

- H3 - Wearing riding boots is conditional.
- H4 - Wearing riding pants is conditional.
- H5 - Using a snaffle bridle is conditional.
- H6 - Using protective horse boots is conditional.

General Hypothesis 3 - The regard for safety rules when riding depends on the circumstances.

- H7 - Compliance with safety rules when riding is conditional.

3. Methods

3.1. Ethical Statement

In accordance with French regulations, this online survey study involved no physical or psychological intervention and posed minimal risk to participants. Participants were informed of the study's aims, guaranteed confidentiality and anonymity, and provided free and informed consent prior to participation. Given the non-interventional nature of the study and the absence of personally identifiable data, formal approval by a Comité de Protection des Personnes (CPP) was not sought.

3.2. Sample

The recruitment technique of "snowball sampling" was used; in this method, research participants were asked to help identify other potential participants. This approach facilitates access to a hard-to-reach population. For this preliminary study on conditionality in the equestrian world, the inclusion criterion was that participants must practice horseback riding. A link to the online questionnaire (Google Form) was initially created and sent to relevant respondents. The resulting sample consisted of 46 riders: 39 women (84.8%) and 7 men (15.2%).

3.3. Questionnaire

The questionnaire included a section for gathering sociodemographic characteristics, questions on perceived risks associated with horseback riding, and the Conditional Scripts Questionnaire (CSQ) adapted to the equestrian context (see **Supplementary Materials** for the full French and English versions of the questionnaire).

Following its initial design [16], the CSQ adapted to the equestrian world is based on several scenarios and situations. The number of scenarios and situations is not methodologically constrained; however, the formulation of the items is. In the initial study [16], there were 8 scenarios encompassing 127 situations.

In this study, we included seven scenarios covering 90 situations. The conditional situations originated from two sources: (1) a phone interview conducted with an equestrian instructor, and (2) informal exchanges with riders at a riding club to better understand the context. Additional situations were adapted from the initial study on road risks (e.g., being with friends, knowing the route, or riding in good weather conditions).

The first six scenarios assessed conditionality regarding the use of equipment (for safety and comfort): riding helmet, safety (or protective) vest, riding boots, riding pants, snaffle bridle, and protective horse boots (or leg gear).

The same 14 situations were applied to these six scenarios (see **Supplementary Materials**, Appendix 1). For example, in the helmet scenario, one proposed situation was: "You sometimes ride a horse without wearing a riding helmet if you go for a short ride..."

These were assessed using a Likert-type ordinal scale with six levels, ranging from absolute compliance (absolutely never) to absolute transgression (absolutely all the time), with four intermediate levels.

The seventh scenario assessed conditionality regarding safety rules (e.g., not standing behind a horse). This last scenario is based on six situations following the same principle (e.g., "you sometimes do not respect safety rules if you trust your equine partner..."; see **Supplementary Materials**, Appendix 2).

3.4. Analysis Strategies

Following the initial method [16], and given that the distributions are ordinal, contingency tables were constructed, first including all scenarios and the six response categories, and then scenario-by-scenario tables. A Monte Carlo chi-square test (χ^2 test with a Type I error rate of 0.05) was performed, followed by quartile analysis.

Quartile analysis involves dividing the population into four equal parts. As in all conditionality studies, the focus was on the third quartile (Q_3 or $q_{0.75}$) of the ordinal distribution, where approximately 75% of the data points lie below Q_3 and about 25% above it. As explained [16], a higher third quartile indicates a more conditional situation, reflecting a greater deviation from the virtuous position of rule adherence. Since 1 corresponds to absolute respect and 6 to absolute transgression, a third quartile close to 1 indicates a low level of conditionality. In the initial study [16], the scenario involving wearing a seatbelt in the front of the vehicle was the only one for which respondents reported absolute compliance with the rule ($q_{0.75} = 1$).

4. Results

4.1. Sociodemographic Characteristics

The average age of the respondents was 28.8 years ($SD = 7.04$). All respondents were horseback riders. In this study, 31 participants were experienced riders, representing 67.4% of the sample. Thirteen participants (28.2%) were at a confirmed level, and two participants (4.3%) were at an intermediate level¹. The majority of riders owned their own horse (see **Supplementary Materials**, Appendix 3 for details).

¹Experienced riders have the level "Gallop 5 and above," confirmed riders have the level "Gallop 3 and 4." https://www.ffe.com/system/files/cavalier/documents/pdf/PROGRAMME_OFFICIEL_GALOPS_EQUITATION_TRAVAIL_1a7.pdf

4.2. Perception of Risks When Horseback Riding

The questions designed to assess the perception of risks when horseback riding revealed responses that were divided between awareness of the risks and less easily controlled factors related to the horse (Table 1).

4.3. The Conditional Scripts Questionnaire

The questionnaire demonstrated a good level of internal consistency [40]; Cronbach's alpha values ranged from 0.83 (safety rules scenario) to 0.98 (protective vest, riding boots, snaffle bridle, and horse boots scenarios) (Table 2).

4.3.1. Calculation Including All Scenarios

The ordinal distributions of the seven scenarios were significantly different from each other, with a Type I error risk of 0.05 ($\chi^2 = 1,720.572$; $p < 0.0001$).

4.3.2. Scenario-by-Scenario Analysis

The scenario-by-scenario analysis did not show significant differences according to the chi-squared test between circumstantial situations and the six response categories.

The least conditional scenario was wearing riding pants, and the most conditional scenario was wearing a protective vest (Table 3).

4.3.2.1. Conditionality of Wearing a Riding Helmet

The ordinal distributions of the fourteen circumstantial situations were not significantly different from each other ($\chi^2 = 75.762$; $p = 0.710$). In this scenario, the q0.75 values ranged from 1 to 3. Most situations had a q0.75 of 1, indicating low conditionality; this was the case for 10 out of 14 situations. The situation with the highest conditionality was "taking your horse from the stable to the arena" (q0.75 = 3). Good weather conditions, familiarity with the route, and going out with one's own horse accounted for slightly more conditionality (in these three cases, q0.75 = 2).

4.3.2.2. Conditionality of Wearing a Protective Vest

The ordinal distributions of the fourteen circumstantial situations were not significantly different from each other ($\chi^2 = 32.762$; $p = 1.000$). This scenario was highly conditional, unlike the previous one, since all 14 situations had a q0.75 of 6. This indicated that this scenario represented an absolute transgression of the rule.

4.3.2.3. Conditionality of Wearing Riding Boots

The ordinal distributions of the fourteen circumstantial situations were not significantly different from each other ($\chi^2 = 41.064$; $p = 1.000$). In this scenario, the q0.75 values ranged from 2 to 4. Within a club riding context, riding a horse that did not belong to the rider ("the equine partner belongs to a riding club" or "the equine partner has been

loaned") and experiencing unfavorable weather conditions generated less conditionality (q0.75 = 2). Conversely, going for a short ride resulted in higher conditionality (q0.75 = 4). The other nine situations had a q0.75 of 3.

4.3.2.4. Conditionality of Wearing Riding Pants

The ordinal distributions of the fourteen circumstantial situations were not significantly different from each other ($\chi^2 = 41.662$; $p = 1.000$). In this scenario, the q0.75 values ranged from 1 to 3. This scenario was the weakest in terms of conditionality, as indicated by the number of situations in which the q0.75 was equal to 1 (N = 11). As in the previous scenarios, the most conditional situation was "going for a short ride" (q0.75 = 3). Taking your horse from the stable to the arena, or favorable weather conditions, accounted for slightly more conditionality (q0.75 = 2).

4.3.2.5. Conditionality of Using a Snaffle Bridle

The ordinal distributions of the fourteen circumstantial situations were not significantly different from each other ($\chi^2 = 31.446$; $p = 1.000$). In this scenario, the q0.75 values ranged from 2 to 3. Similar to scenario 4 (wearing riding boots), riding in a club context, where the rider does not ride their own horse, and adverse weather conditions resulted in lower conditionality (q0.75 = 2). Other situations also exhibited reduced conditionality, such as being in the company of friends, having the route be known to the horse, going for a horseback ride, and riding on a trail in good condition (eight situations).

Six situations led to higher conditionality (q0.75 = 3): taking the horse from the stable to arena, going for a short ride, being the horse owner, practicing, the rider having previous knowledge of the route, and favorable weather conditions.

4.3.2.6. Conditionality of Using Protective Horse Boots

The ordinal distributions of the fourteen circumstantial situations were not significantly different from each other ($\chi^2 = 33.302$; $p = 1.000$). In this scenario, the q0.75 values ranged from 4 (for 5 situations) to 5 (for 9 situations); therefore, it can be stated that this scenario demonstrated greater conditionality than the previous ones. Lower conditionality was observed when riding in a club context (regardless of whether the rider was the owner or not) and during practice.

4.3.2.7. Conditionality of Compliance With Safety Rules

The ordinal distributions of the six circumstantial situations were not significantly different from each other ($\chi^2 = 41.870$; $p = 0.231$). In this scenario, the q0.75 values ranged from 2 to 4. The most conditional situation was trusting one's equine partner (q0.75 = 4). The least conditional situations were those related to forgetting or not knowing the rules.

Table 1: Perception of risks when horseback riding.

1. I believe that riding regularly reduces the risk of having an accident.				
1 (Strongly disagree)	2	3	4	5 (Strongly agree)
24% (N = 11)	17% (N = 8)	26% (N = 12)	26% (N = 12)	7% (N = 3)
2. I believe that self-confidence reduces the risk of having an accident.				
9% (N = 4)	11% (N = 5)	17% (N = 8)	46% (N = 21)	17% (N = 8)
3. I believe that trusting my equine partner reduces the risk of having an accident.				
11% (N = 5)	13% (N = 6)	33% (N = 15)	35% (N = 16)	9% (N = 4)
4. I believe I would take fewer risks when horseback riding if...				
Statement	Strongly disagree	Disagree	Agree	Strongly agree
...my equine partner belonged to me.	6 (13%)	16 (35%)	18 (39%)	6 (13%)
...my equine partner belonged to a riding club.	10 (22%)	20 (43%)	15 (33%)	1 (2%)
...my equine partner was loaned to me.	18 (39%)	22 (48%)	4 (9%)	2 (4%)
5. As a rider, do you consider horseback riding to be a dangerous sport?				
Yes = 82.6% (N = 38)		No = 17.4% (N = 8)		
6. In your opinion, what are the potential risks associated with horseback riding?				
Risk factors		Percentage		Number
Falls from horseback		80.4%		N = 37
The horse's behavior (biting, trampling, fear, hoof kicking, unpredictability, etc.)		30.4%		N = 14
Consequences of equestrian risks (minor injuries, serious injuries, quadriplegia, and death)		23.9%		N = 11
The rider's behavior (lack of control, mistreatment, non-compliance with safety rules)		13%		N = 6
Environmental risks (trail conditions, weather, third parties, vehicles, etc.)		8.7%		N = 4
7. In your opinion, what are the most effective ways of reducing the risks associated with horseback riding? (Multiple answers possible)				
Experience 82.6% N = 38	Habits 23.9% N = 11	Self-confidence 21.7% N = 10	Trusting one's equine partner 58.7% N = 27	
Equipment 67.4% N = 31	Training and supervision 76.1% N = 35	Environment 65.2% N = 30	Other 10.9% N = 5 (See Supplementary Materials , Appendix 4)	

5. Discussion

In this study, for the first time, the concept of conditionality was adapted to the equestrian world, which faces numerous injuries and fatalities [3]. Thus, the theory of conditionality was applied to the man-horse relationship, involving two entities to be protected. Horses are not passive recipients (like vehicles); they are social beings capable of feeling human emotions [7,29]. Several hypotheses were proposed regarding the conditionality of wearing equipment (for safety and comfort; H1 to H6) and the conditionality of compliance with safety rules (H7). In line with these hypotheses, the

results from the CSQ applied to the equestrian world demonstrated that all scenarios were conditional. The concept of conditionality [14,41] links the notions of prescription and condition, enabling the development of normative flexibility. The approach of conditionality in the field of social thinking opposes an absolute conception of norms and advocates for the existence of conditional normative variations [1,2].

A significant difference was observed in the ordinal distribution when the seven scenarios were grouped

together. This confirms the existence of differences in conditionality depending on the scenario. On the other hand, the scenario-by-scenario analysis showed that there were no significant differences in the conditionality of circumstantial situations. These results can be interpreted as reflecting very homogeneous data, as 5 out of 7 scenarios had a p-value of 1. This indicates that intra-scenario conditionality is consistent across all situations, which are more or less conditional.

Among the seven scenarios, wearing an equestrian helmet was one of the two scenarios with the lowest conditionality. However, it does not guarantee absolute compliance with the rule, as is the case for wearing a seatbelt in the front seat of a car [16]. Therefore, Hypothesis 1 was validated. It should be noted that wearing an equestrian helmet is highly recommended but not mandatory, except for minors. The main situations justifying not wearing a helmet were: good weather conditions, prior knowledge of the route, being the horse's owner, and transporting the horse from the stable to the arena. As can be seen, riders expose themselves to risks, since head injuries are responsible for horse-related fatalities [4,36,37,42,43]. In April 2023, the International Equestrian Federation established a new working group: the "FEI Helmet Working Group," with the goal of developing strategies to reduce the risk of serious head injuries.

In contrast, the scenario involving wearing a protective vest was the most conditional. The results largely support Hypothesis 2, as the third quartile was consistently at 6 across all situations. In this scenario, we observed an absolute transgression, which has never been seen within the context of conditionality, unlike the absolute compliance observed with wearing a seat belt in the front seat of a car [16]. Such vests protect the rider's chest by softening and absorbing the impact in the event of a blow or a fall from horseback. A protective shell encases the wearer's body, offering good protection for the back, spine, ribcage, and abdominal organs. Despite these benefits, riders claimed to be aware of the risks involved in horseback riding, with 82.6% stating that riding was a dangerous sport and 67.4% believing that equipment helps reduce these risks. Wearing a safety vest did not appear to be a practice among the riders in this sample, even though it can enhance their safety [44]. This result may also be attributed to the fact that this vest was originally designed for the cross-country phase of the eventing competition [45].

Table 2: The number of situations in each scenario and the internal consistency index.

Scenario	Number of situations	Cronbach's alpha
Riding helmet	14	0.95
Protective vest	14	0.98
Riding boots	14	0.98
Riding pants	14	0.97
Snaffle bridle	14	0.98
Protective horse boots (or leg gear)	14	0.98
Safety rules	6	0.83

Table 3: Scenarios ordered by increasing quartile q0.75 (from least to most conditional).

Scenario	q0.75
Riding pants	1.286
Riding helmet	1.357
Snaffle bridle	2.429
Riding boots	2.786
Safety rules	2.833
Protective horse boots (or leg gear)	4.643
Protective vest	6.000

Hypothesis 3 addressed the conditionality of wearing equestrian riding boots. Although today it is common for riders to wear mini-chaps and ankle boots, wearing riding boots remains essential for maximum protection of the rider's legs and the comfort of the animal. They reduce constant friction against the saddle, prevent stirrup straps from pinching, and provide proper leg stability. It is important to note that wearing riding boots is primarily a matter of comfort. The results confirmed our hypothesis. The most common reason for not wearing riding boots was going for a short ride. Conversely, the least conditional situation was when the horse belonged to a riding club.

The conditionality of wearing riding pants was also verified (Hypothesis 4), but it was not assumed that the conditionality would be weakest in this scenario. Riding pants are a necessary piece of clothing for riding, as they make it easier to sit comfortably in the saddle and reduce discomfort (e.g., chafing, rubbing, etc.). However, it can be noted that some beginners are rather reluctant to invest in riding pants, preferring to ride in leggings or jeans. Eleven out of the fourteen situations had a q0.75 of 1, which corresponds to absolute compliance with the rule (i.e., the riders questioned are not beginners). In this scenario, the situations that most accounted for not wearing riding pants were: taking the horse from the stable to the arena, going for a short ride, and good weather conditions.

The hypotheses related to the horse's equipment were also verified (Hypothesis 5 and Hypothesis 6). A snaffle bridle is a harness designed for horses that secures the bit and reins, allowing the rider to maintain contact with the horse's mouth. This enables the rider to regulate the horse's gait and direction. The situations in which a snaffle bridle was most often not used were: when taking the horse from the stable to the arena, going for a short ride, owning the horse, and during practice. The situations least conducive to transgressions were when riding in a pony club with a horse that did not belong to the rider, and when in the company of friends.

The use of protective horse boots is primarily a measure to safeguard the horse's legs during various sporting disciplines, but also to protect the horse from itself, as it is not uncommon for horses to injure their own limbs. This situation was highly conditional, and the main reasons for not using protective horse boots were: going for a short ride;

the trail being in good condition; and the horse and rider being familiar with the trail.

Protective vests, helmets, and riding boots help reduce the risk of serious injuries and offer essential safety. For the horse, well-fitted bridles, saddles, and protective leg gear prevent injuries and discomfort². In this study, the use of equipment appeared to be conditional, for example, when the rider rode their own horse. Whether the rider is the owner or not, the horse must be protected. A study showed the associations between horse behavior and the equipment used [46]. A key aspect of equine rehabilitation therapy is ensuring the comfort and well-being of the horse. During the rehabilitation phase, the right boots can significantly reduce the stress and discomfort experienced by horses³.

The conditionality observed in most situations is similar to that found in driving situations, while the interaction in the present study is based on the man-horse relationship rather than the man-vehicle relationship. Indeed, road conditionality also depends on weather conditions, route familiarity, road quality, the length of the journey, the presence of friends, the vehicle driven (for scenarios 1 to 6), or even the perception of the rules as unnecessary (scenario 7) [16,19].

Overall, our findings indicate that riding with one's own horse generates more conditionality, while riding with a horse belonging to a riding club generates less conditionality. The interpretation of these results is twofold. First, in a riding club context, certain rules become mandatory. Second, riders are more confident when riding their own horse, allowing them to take more "normative latitudes" [2,16]. This is a typical case of risk homeostasis [47]. According to the Risk Homeostasis Theory, if an individual perceives the level of risk as relatively low, they may modify their behavior and increase their exposure to risk. Conversely, if they perceive a higher level of risk, they may become more cautious. The importance of confidence perceived in the animal illustrates the indelible rider/horse bond that has strengthened over time [26]. Whether or not the horse belongs to the rider, certain measures, such as those promoting the well-being of the animal (e.g., equipment to improve comfort), should be widely adopted. If horses contribute to human mental health [33–35], then humans must also contribute to animal welfare.

The animal is not a passive recipient, and it is essential for those engaging in activities with horses (companionship, sport, etc.) to consider the tactics used to "create a positive experience for the horse" [30]. Since they are managed and trained by humans, horses are sensitive to human behavior [6]. The well-being and abilities of the horse, as well as the safety of people, can be impacted by stressful situations that generate emotional overexcitement [48]. Additionally, links have been established between horse welfare and rider satisfaction [49]. Another parallel can be drawn regarding

horse transport, as the stress experienced by humans during transportation [50] is also experienced by horses [51]. Just as the analysis of the road context must incorporate various variables (human, vehicle, and environment), the equestrian context requires a systemic approach. A study has looked into the application of the Workplace Health and Safety Framework (WHS) in work and non-work equestrian environments [3]. The analysis considers the various dimensions of risk during human-horse interactions. According to the findings, this framework can help reduce horse-related human injuries and deaths by fostering a proactive culture of equine safety. Another study identifies four aspects of horse-related risk: the risk itself, the horse, the rider, and the cultural context in which equestrian activities occur [52].

This preliminary approach to conditionality in the equestrian environment provides insights into what riders consider legitimate to transgress regarding comfort and safety rules. The Conditional Scripts Questionnaire, through its contextualization design, allows for the highlighting of these legitimate transgressions within the representation. An advantage of this questionnaire is that it was designed to circumvent the issue of social desirability [2,16], a key concern in surveys. For example, when examining perceptions of horse welfare, a gap has been identified between riders' public statements and private beliefs [53].

6. Limitations

Nevertheless, this study has certain limitations, particularly regarding the population and its relationship with practices. The question of practices within the field of social representations is crucial: "Practices are necessarily linked to social representations, which defined as guides for action or 'representational actions' [1]." Several studies on conditionality are based on small samples, and in the field of social thinking, the criterion of representativeness is generally not considered relevant [16,21,23], once a criterion of population homogeneity is established, specifically, the practice of horseback riding in our case. However, in this study, the only inclusion criterion was the practice of horseback riding. Nevertheless, this practice can vary significantly, especially if the respondents are involved in competitions, for example. It is evident that these situations could be further explored in this context.

For instance, considering the example of wearing protective vests which, in our sample, indicates an absolute transgression, a cross-country situation among practitioners might lead to adherence to the rule. Similarly, in the road sector, we know that conditionality is influenced by sociodemographic variables such as age and gender, and these variables are systematically taken into account. Most respondents in our study are experienced riders. Young people tend to be more conditional than older motorists or motorcyclists, but very young drivers on probationary licenses may be less conditional than young drivers overall [19,21].

In the equestrian field, some studies have explored the links between novice riders and accidents. It has been shown that novice riders are much more likely to get injured than more experienced riders. They are three times more likely than

²<https://www.huntleyequestrian.com/blogs/press/how-to-choose-the-perfect-equestrian-gear-for-comfort-and-safety#:~:text=Protective%20vests%2C%20helmets%20and%20sturdy,move%20freely%20and%20perform%20optimally>

³<https://sbleathers.co.uk/the-role-of-riding-boots-in-equine-rehabilitation-therapy/>

intermediate riders, five times more than advanced riders, and nearly eight times more than professional riders [54]. In this study, the majority of respondents are women, who tend to have a different relationship with risk compared to men [55], and are generally more empathetic in their interactions with others [18]. As studies on conditionality suggest, one might expect a predominantly male sample to exhibit higher levels of conditionality [20,21]; therefore, it would be relevant to verify this hypothesis. In a study [56], men were 2.2 times more likely than women to be included in the fatal sample.

Finally, it seems relevant, as is common in the field of driving, to record experiences of injuries and accidents that could influence the conditionality and context of the practices of the riders in question.

7. Conclusion

Following these results, to prevent risks and improve equine welfare, we can focus on false beliefs, risk perception, and cognitive dissonance mechanisms [47,57]. Regarding the first point, riders believe that there are fewer risks when they practice with their own horse, take a short journey, or when the weather is good. These false beliefs are also observed in road safety, where, for example, more accidents occur during good weather, on straight roads, on familiar routes, and when seat belts must be worn even on short trips. Horses, whether they belong to us or not, have feelings.

Concerning the second point, riders state that they are aware of the risks and that equipment can help mitigate those risks, but their use is often conditional. With horse welfare as a priority, riders need to be more aware that their beliefs and practices do not always align with the animal's well-being. Just as riders are weakly conditional regarding their own comfort (for example, wearing riding pants), they should also be attentive to the comfort of the animal (such as using protective horse boots).

Supplementary Materials

The Supplementary Materials include the full French and English versions of the questionnaire used in the study, as well as four appendices providing additional data. Appendix 1 and Appendix 2 present the conditional scenarios and situations explored in the questionnaire. Appendix 3 details the sociodemographic characteristics of the respondents and their equine partners. Appendix 4 includes participants' open-ended responses regarding effective strategies for reducing horseback riding risks.

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Authors' Contributions

SG: Conceptualization, Formal analysis, Validation, Writing – Original draft, Writing – Review & Editing. FB: Conceptualization, Exploratory interviews and questionnaire administration, Writing – Original draft.

Data Availability

All data supporting the findings of this study are available within the article and its **Supplementary Materials**.

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Conflicts of Interest

The authors declare that they have no conflicts of interest.

Ethical Approval

In accordance with French regulations, this online survey study involved no physical or psychological intervention and posed minimal risk to participants. Participants were informed of the study's aims, guaranteed confidentiality and anonymity, and provided free and informed consent prior to participation. Given the non-interventional nature of the study and the absence of personally identifiable data, formal approval by a Comité de Protection des Personnes (CPP) was not sought.

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Effect of Age on the Date of First Ovulation in Mares Subjected to an Artificial Lighting Regimen During Seasonal Anestrus

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Abstract

Previous studies have shown that artificial lighting can reduce the duration of anestrus in the horse. Here, we investigated whether age can affect the date of first ovulation in mares subjected to an artificial lighting regimen beginning before the winter solstice. Mares ($n = 224$) of different breeds aged 1 to 27 years were divided into five groups by age: a) 1–5 years ($n = 71$), b) 6–10 years ($n = 38$), c) 11–15 years ($n = 44$), d) 16–20 years ($n = 30$), and e) 21–27 years ($n = 16$). 25 mares apparently failed to respond to treatment and were excluded from the analysis. Light treatment began on a mean starting date of November 27. Ovulation was determined through transrectal ultrasonography at regular intervals. The age of the mare significantly influenced the date of first ovulation, with mares aged 1 to 5 years ovulating significantly earlier than all other age groups ($P < 0.01$). The interval from the start of treatment to ovulation in this group was shorter than for all other groups. A significantly larger proportion of mares in the youngest group (25.7%) ovulated before February 1 compared to all other age groups combined (6.9%). The proportion of mares that failed to respond to treatment was significantly larger in mares older than 15 years ($P < 0.01$). These results show that under winter artificial lighting, first ovulation occurs earlier in young mares, likely due to a lessened entrainment to the natural photoperiod.

Keywords

Circannual rhythms; horse; estrous cycles; ovulation; photoperiod, seasonal breeding

1. Introduction

In temperate climates, mares are seasonal breeders, entering a period of ovarian inactivity with declining daylight. The entry into anestrus and the vernal transition to ovarian cyclicity have been comprehensively described in [1]. However, unlike the spring transitional period that leads to the resumption of ovarian cycles within a defined timeframe [2], the autumn transitional period that leads to anestrus (if the term 'transitional' is applicable here) is variable. Younger mares and those on a reduced caloric balance may have a final ovulation as early as August in the Northern Hemisphere, whereas the majority continue to cycle into winter, ceasing ovarian activity in November or

December [3]. Data from this Clinic showed that occasional mares may cycle into January or even February before entering an anestrus phase until April or, rarely, even May. A small percentage of mares continue to cycle throughout the winter, even under outdoor conditions [4]. At lower latitudes, however, it was found that 55% of 11 mares cycled all winter [5].

The mean date of the first seasonal ovulation at the latitude of this Clinic (53°N), where previous studies were undertaken [4], is April 23rd, with no more than a 4-day variation between seasons (unpublished). In Finland, however, at a latitude of 61°N, only 14% and 62% of barren mares were found to be cyclic by the end of April and May, respectively [6]. They

noted that 3-year-old mares in work ovulated earlier than the barren mares, with 26% and 97% of 3-year-old mares cyclic by the end of April and May, respectively, compared with 14% and 68% of the barren mares. This difference was attributed to differences in feeding, exercise, and stable lighting rather than age. It was also observed that mares younger than 5 years stopped cycling earlier than older mares [7], and that mares older than 15 years took longer to begin cyclic ovarian activity. At our clinic, a previous study showed that all four 3-year-old mares had stopped cycling by the end of September, compared with only 3 of the 17 older (4- to 25-year-old) mares [4].

It was originally reported that exposure to artificial lighting during late winter or early spring significantly reduced the duration of anestrus in mares [8], and subsequent studies revealed that extending the light phase of the 24-hour light:dark cycle from 12 hours to 14.5–16 hours a day was effective in hastening the onset of ovarian cyclicity [9–13]. Thus, this light treatment has been widely used in our clinic to enable early conception. Since earlier publications had suggested that the best effect could be obtained with a lighting regimen started at the end of December or early January (Northern Hemisphere), this strategy was adopted for years. Later, however, we found that ovulation could be advanced further by starting an earlier light regimen. During the analysis of data recorded over many seasons, it was noticed that this advancement was even more effective in young mares. This study was therefore undertaken to determine whether age affects the time of first ovulation in mares subjected to an artificial lighting regimen during seasonal anestrus.

2. Materials and Methods

Seasonally anestrous mares, used both for breeding and as embryo transfer recipients, were studied to determine the effect of age on the date of the first ovulation following treatment with artificial lighting in an outdoor arena equipped with floodlights that imparted a light intensity of approximately 300 lux at the level of the horse's head. Daylength was extended to at least 16 hours, beginning at dusk and ending at midnight. The data were gathered from 32 seasons of observations.

Mares ($n = 224$) aged 1 to 27 years (mean = 12 years), including Irish Draught and other breeds and crossbreeds, were maintained at pasture until the beginning of light treatment, at which point they were corralled in the arena under 16 hours of light. The large majority of mares had been wintered under ambient light in the years prior to treatment. Mares were fed *ad libitum* baled haylage in the arena and at pasture when grass became scarce. All mares were in good body condition (scores 5–8) from the beginning of treatment until ovulation. Photoperiodic conditions were the same each season.

Mares were examined per rectum with ultrasound at regular intervals during the autumn transition into anestrus to determine the final ovulation of the breeding season. Mares that continued to ovulate after the beginning of light treatment were excluded from the study if the interovulatory interval between the last ovulation and the first ovulation of the next season was less than 60 days. Anestrous mares were examined every 2–3 weeks, then with increasing frequency,

from every 4–5 days to daily, and finally three times daily as follicle diameters and edema scores increased preceding the first ovulation. Some young mares were already in deep anestrus when first examined prior to treatment, and therefore, the date of the last ovulation was not known; otherwise, the date of ovulation was determined to within 24 hours. All ovulations were spontaneous. No mare was given any ovulation-inducing treatment.

Most mares ($n = 199$) first ovulated following treatment between December 16 and March 31. Mares that ovulated later than March 31 ($n = 25$; 11%) were deemed to have failed to respond to the lighting regimen and were excluded from the analysis.

For analysis, mares were divided into five groups by age: a) 1–5 years ($n = 71$), b) 6–10 years ($n = 38$), c) 11–15 years ($n = 44$), d) 16–20 years ($n = 30$), and e) 21–27 years ($n = 16$). Light treatment began on a mean date of November 27 (range: November 17 to December 11). The individual mean dates for the start of light treatment for each age group were November 25, November 26, November 29, November 28, and November 24 for age groups a–e, respectively.

2.1. Statistical Analysis

Continuous data (e.g., the interval between February 1 and the first ovulation of the year) were tested for normality using the Anderson-Darling test. As the data were not normally distributed, the effect of mare age on the day of the first ovulation was determined using the non-parametric Kruskal-Wallis test, followed by the Mann-Whitney test for pairwise comparisons.

It is important to note that although we acknowledge that a multifactorial analysis could have been employed to account for possible effects of individual mares, a given year, etc., the main objective of the study was specifically to determine the overall effect of mare age on the variables of interest. Categorical data (e.g., the proportion of mares ovulating before February 1) were examined using the Chi-square test.

3. Results

The mean date of the start of treatment (November 25, 26, 29, 28, and 24) did not differ between age groups (Table 1).

The median interval from February 1 to the first ovulation of the year was influenced by mare age group ($P < 0.001$). The youngest group (mares aged 1–5 years) ovulated earlier than any of the other age groups ($P < 0.001$). The median interval between mares aged 6–10 years (16.5 days) and those older than 15 years (19.5 days) was significantly different ($P = 0.029$). The individual median intervals from February 1 to the first ovulation were 8.5, 16.5, 15.5, 19.5, and 19.5 days for age groups 1–5, 6–10, 11–15, 16–20, and 21–27 years, respectively.

The mean interval from the start of treatment to ovulation for the youngest group (75 days) was shorter than for all other groups (mean interval range for the other age groups: 81–88 days) (Table 1).

A significantly ($P < 0.01$) larger proportion of mares in the youngest group (25.7%) ovulated in December or January (before February 1) compared with all other age groups combined (6.9%) (Figure 1).

Table 1: Mean dates for the start of artificial light treatment and first ovulation, time (days) elapsing between the start of light treatment and first ovulation, and the number and proportion of mares ovulating before February 1 in groups of mares aged: a) 1 to 5, b) 6 to 10, c) 11 to 15, d), 16 to 20, and e) 21 to 27 years.

Age Group	a	b	c	d	e	Failed to respond
Age (years)	1–5	6–10	11–15	16–20	21–27	
n	70	38	44	31	16	25
Start date of long-day treatment	25.11	26.11	29.11	28.11	24.11	26.11
Range of dates	17.11–3.12	9.11–4.12	21.11–7.12	23.11–9.12	8.11–11.12	1.11–10.12
Mean date of first ovulation	9.2*	21.2	19.2	21.2	20.2	24.4**
Range of dates between individuals	16.12–28.3	20.1–29.3	25.1–30.3	27.1–21.3	13.1–28.3	
Start of long-day treatment to ovulation (days)	75*	87	81	85	88	146
Range within groups (days)	67–83	69–94	72–95	79–91	61–104	
Number of mares that ovulated before February ^{1st}	18*	1	5	1	2	
% of mares that ovulated before February ^{1st}	25.7*%	2.6%	11.4%	3.2%	11.8%	

* $P < 0.001$ for mares aged 1–5 compared to all other groups; ** $P < 0.001$ for mares that failed to respond to light treatment compared to mares that did respond.

The mean start date of treatment for mares that failed to respond ($n = 25$) was not different (November 26) (Table 1). The mean date of first ovulation in these mares (April 27) was significantly different from that of all other groups (February 16). The mean age of outliers was not different (12.6 years) but was not evenly distributed; among mares aged 16 to 27 years, 25.5% were outliers, compared with 8.6% in mares aged 1 to 15 years.

Had the outliers been included in the analysis, the mean ovulation date for mares aged 1 to 5 years (February 14) would have been significantly different from all other age groups (February 25.4, February 23.6, March 5.0, and March 5.3 for groups b to e, respectively).

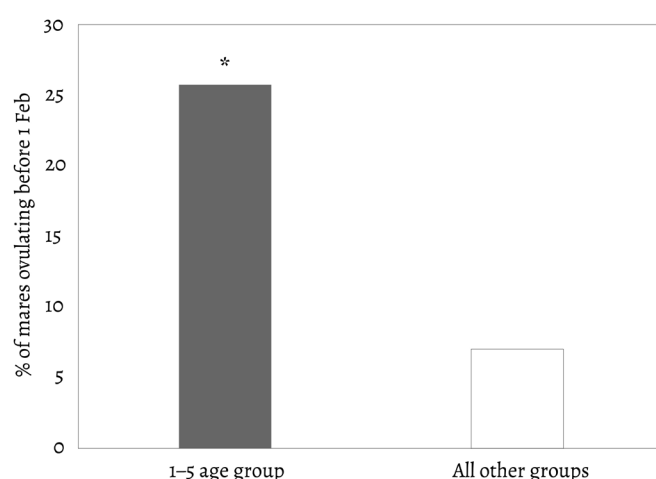


Figure 1: Effect of age on the proportion of mares ovulating before February 1 in mares subjected to an artificial lighting regimen designed to increase the duration of the light phase of the 24-hour light:dark cycle to 16 hours per day during seasonal anestrus. The average start date of light treatment was November 27; lights were turned on at the beginning of dusk and off at midnight. * $P < 0.001$ for mares aged 1 to 5 years compared to all other age groups combined (6 to 27 years).

4. Discussion

The results of this study show that the duration of seasonal anestrus in mares subjected to an artificial lighting regimen during the winter is significantly affected by age and reveal that, under these experimental conditions, first ovulation occurred earlier in young mares (1–5 years) compared with their older counterparts. This study was not undertaken to investigate the effects of artificial lighting on the duration of seasonal anestrus per se, as this effect is already well established [1,3,8–13].

In the current investigation, the mean date of the first ovulation in 3-year-old mares was February 9.7th, and for 1- to 5-year-olds, it was February 8.1th. Mares older than five ovulated, on average, about 11–12 days later (February 20th). These results are in agreement with previously reported findings in Finn Horses [14], where 3-year-old mares subjected to artificial lighting were shown to exhibit an earlier onset of seasonal activity than older mares (6 to 14 years). In that study, 67% ($n = 8$) of 3-year-old mares were cyclic by the second week of February, compared with only 13% ($n = 2$) of mares in the older group (>3 years), whereas by the fourth week, 92% of 3-year-old mares were cyclic compared with 63% of older mares. In our study, the mean dates for 3-year-old and older mares were February 9th and February 20th, respectively, which are comparable to the previously reported dates of February 13th and February 23rd for similar age groups [14]. Both studies show that, when subjected to an artificial lighting regimen designed to increase the duration of the light phase of the 24-hour cycle during the winter, mares under the age of six ovulate about 10 to 12 days earlier than older mares. In our study, there was also a difference between mares aged 6 to 10 years and all mares older than 15 years.

In the current study, the majority of mares had previously been kept at grass under ambient light conditions during most winters. In a related study [14], no data were provided regarding whether mares had been exposed to

ambient or artificial light in prior seasons. However, it was confirmed that although those mares were housed, they had never been subjected to an artificial lighting regimen in previous winters (T. Katilla, personal communication). In both studies, therefore, it appears that most mares had been wintered under ambient light conditions for several years. It is possible that older mares were more strongly entrained to ambient light conditions, which regulate the timing of the first ovulation of the year. At our clinic, this occurs consistently around April 23rd. It appears that this entrainment may have, to some extent, impaired the response to the increase in daylength that began around two months earlier.

We have previously shown that horses are extremely sensitive to light cues and that the influence of photoperiodic signals on circadian biological rhythms in this species is different from the way in which light regulates their circannual physiological cycles [15]. Indeed, we have shown that whereas horses display weak circadian rhythms that are masked by the 24-hour light:dark cycle, thus allowing a rapid resetting following a photoperiodic phase shift [16], they possess extremely strong circannual rhythms which are entrained to a 12-month cycle by the prevailing photoperiod. This is a strategic mechanism of adaptation to the environment which, to some extent, relates to the different anatomical basis of the circadian and circannual clocks and the way light signals control them [17,18]. Indeed, whereas the circadian master clock is located in the suprachiasmatic nucleus of the hypothalamus and is entrained by the 24-hour light:dark cycle mainly, although not exclusively, through a monosynaptic pathway from the retina [19,20], the circannual master clock resides in the pars tuberalis of the pituitary gland and is primarily entrained to a 12-month cycle by the nocturnal secretion of melatonin from the pineal gland [21–24]. Due to the robustness of circannual biological rhythms in this species (e.g., reproduction, hair growth, metabolism), resetting a rhythm once it has been entrained by the local photoperiod is difficult to attain and can take up to a full year (D.J. Tortonese, unpublished observations). Thus, the finding in the current study that, under an extended light phase during winter, the first ovulation after anestrus occurred significantly earlier in young mares can be attributed to a reduced robustness of their circannual cycles. This contrasts with the older mares, who had been exposed to the natural photoperiod for many more circannual cycles and had fully adapted their annual reproductive physiology to the local 24-hour light:dark cycle. As several mares in this investigation were assessed across a number of years, further studies will be able to ascertain a putative increase in the robustness of circannual cycles over time, as well as possible effects of individual mares, specific years, and their interactions on the first ovulation after anestrus.

5. Conclusion

Young mares subjected to artificial lighting were found to ovulate significantly earlier than all other age groups. These findings are attributed to a reduced robustness in the circannual cycles of young mares.

Authors' Contributions

J.R.N. collected and documented the data. D.J.T. helped analyze the data and write the paper, including the statistics and discussion.

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

No conflicts of interest to be disclosed

Ethical Approval

Ethical approval was not required since there are no experimental procedures.

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Comparison of Transverse Thoracolumbar Angles in Dressage and Endurance Horses Using 3D Light Scanning and Comparison with Commercial Saddle Gullet Angles

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Abstract

The thoracolumbar profile is of interest in relation to saddle design and saddle fit. Flexible-curve rulers have previously been used to gather thoracolumbar profiles in horses; however, 3D light scanning offers a potential non-contact alternative method to estimate the cross-sectional shape of the region in greater detail. The aims of this study were to (1) describe the thoracolumbar profiles of endurance and dressage horses using 3D light scanning and (2) compare the wither profiles to saddle manufacturers' gullet bar angles. 3D light scans of the thoracolumbar region were obtained from 23 fit and competing Arabian endurance horses and 21 dressage horses of mixed breed competing at advanced or higher, each from two different stables. Markers were placed by palpation on the caudal scapula (V1) and T18 (V4). Images were imported into Meshmixer. A transversely oriented plane cut was taken at the level of the marker of the left caudal scapula, perpendicular to the back surface (V1), and at the level of the marker at T18. Two further cuts were made at the base of the withers (V2) and the lowest point/midpoint of the back (V3). The mean transverse back angle at V1 was $87 \pm 8^\circ$ for the endurance horse sample and $99 \pm 10^\circ$ for the dressage horse sample ($P < 0.0001$), and at V4 was $141 \pm 7^\circ$ (endurance) and $144 \pm 6^\circ$ (dressage) ($P < 0.0001$). For both endurance horses and dressage horses, there was a significant effect of location on back transverse angle (V1 to V4; $P < 0.001$), with V1 the narrowest and V4 the widest. While there is little consistency in what gullet angle a "medium" gullet bar would actually be, the range of angles measured at the shoulder in the present study reflects the most common gullet sizes offered by six manufacturers of English saddles.

Keywords

Back; equestrian; riding; equine; morphometry

1. Introduction

Knowledge of the back shape is important for saddle design and saddle fitting. Traditionally, saddle fitters, saddle makers, and researchers have used flexi-curves to take templates of horses' backs for different purposes [1–4]. In addition, a number of commercial systems exist for obtaining back dimensions, including physical/mechanical systems [5] and smartphone-based light scanning systems (HorseShape

Smart 3D Scan App, TZK, TechnologieZentrum Koblenz, Universitätsstr. 3, 56070 Koblenz, Germany).

Three-dimensional (3D) light scanning as a method of data collection is still a relatively new approach in its application to horses, but has been suggested to be reliable for measuring trunk and limb volumes [6,7], transverse epaxial muscle symmetry in the thoracolumbar region [8], and general body morphometry [9,10].

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Light scanning technologies have become fundamental in diverse scientific and industrial fields, including 3D modeling, biomedical imaging, and quality assurance. Traditional methods, such as laser scanning, structured light scanning, and time-of-flight (ToF) scanning, each offer unique advantages. Laser scanners use coherent beams to map surfaces with high precision, which is especially effective over longer distances [11]. Structured light systems project known patterns onto surfaces and analyze distortions to generate high-resolution 3D models, making them well suited for capturing detailed geometries [12]. ToF scanners measure the travel time of light pulses to reconstruct depth information, enabling rapid scanning over large areas, albeit with generally lower resolution [13]. More recently, the proliferation of smartphone-based scanning technologies has significantly expanded access to 3D scanning. Many modern smartphones are now equipped with front-facing cameras capable of depth sensing through structured light, and increasingly with LiDAR sensors that use ToF principles to generate depth maps in real time [14]. These mobile systems, while typically less accurate than professional-grade equipment, offer portability, affordability, and real-time feedback, making 3D scanning more accessible than ever before.

The aims of the present study were to use the previously established technique by Tabor *et al.* [8] to obtain scans of two sets of endurance and two sets of dressage horses in order to characterize the thoracolumbar transverse angles at the level of the caudal aspect of the shoulder and the base of the withers, lowest/midpoint of the back, and T18 with respect to position and horse type/use. In addition, a secondary aim was to compare the wither profiles to saddle manufacturers' gullet bar angles. Alignment between the range of angles measured at the withers and the range of angles offered by saddle manufacturers was anticipated.

2. Materials and Methods

2.1. Horses

A convenience sample of 23 Arabian endurance horses in full training and competing at FEI CEI*** levels with two different trainers, and 21 dressage horses competing at Advanced or higher at two stables, were recruited for the study (Table 1). All horses were considered by the trainer and the attending veterinary surgeon to be free of overt lameness or obvious musculoskeletal asymmetry. Scanning was undertaken in rooms or locations with which all horses were familiar.

Table 1: Signalment of horses used in the present study (m = mare; g = gelding).

Stable	n	Sex	Age	Breed
Endurance 1	16	4m/12g	8 ± 2	Arabian
Endurance 2	7	4m/3g	11 ± 3	Arabian
Dressage 1	15	3m/12g	9 ± 4	Warmblood/Warmblood x Hanoverian
Dressage 2	6	5m/1g	13 ± 1	Warmblood/Warmblood x

2.2. Scanning Equipment

The equipment used for scanning was as described previously by Tabor *et al.* [8]. Images were obtained using a Structure Sensor (STO1) mounted on an 11-inch iPad Pro with the Structure Sensor Bracket (Model SA21) (Occipital Inc., Boulder, Colorado, 80302, USA). Images from the iPad were sent over Wi-Fi to Skanect Pro Software (V1.1, Occipital Inc.) running on a Lenovo Ideapad 500 laptop. The connection between the iPad and the laptop was via a 300 Mbps nano-router in AP mode connected to the laptop (TL-MR3020 ver. 3.2, TP-Link, Unit 2 & 3 Riverview, Cardiff Road, Reading, RG1 8EW, UK). This was found to provide a more stable and reliable connection than connecting directly to the laptop Wi-Fi. The wide-angle lens option supplied with the Structure Sensor was not used, as initial trials suggested the iPad standard camera lenses were adequate. The calibration of the Structure Sensor was performed according to the manufacturer's instructions. The settings in the Skanect Software were: Recording Feedback: CPU; Feedback Quality: Low; Offline Recording: Key Frames; Force QVGA: ON; Track Loss Detection: On; Uplink Mode: Depth & Color; Uplink Color Gain: Locked on Record. The specific scan settings were set as: Scene: Body; Bounding Box: 1.8 meters; Aspect Ratio: Normal. Scanning was initiated and terminated on the iPad.

2.3. 3D Light Scan Protocol

The scanning protocol was as described previously [8]. Briefly, 20-mm white polystyrene hemispherical markers were placed on the caudal aspect of the left and right scapula, and a third marker was attached to the midline of the spine at the cranio-caudal level of T18, identified by palpation from the last rib. Each horse was scanned at a distance of approximately 1.5 m, three times. Files were exported as STL files.

STL files were imported into Meshmixer (V3.5.474, 2017, Autodesk Inc., San Rafael, California, United States). A wireframe was applied to the images, then the processed images were saved as Meshmixer files (.mix). Example images are shown in Figure 1, Figure 2, and Figure 3.

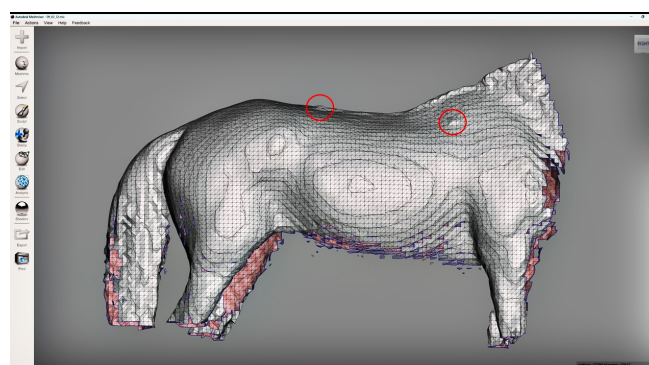


Figure 1: Example of a 3D scan of a horse imported as an STL file into Meshmixer and viewed from the right side, with 20 mm polystyrene markers placed on the caudal scapula and T18, as identified by palpation.

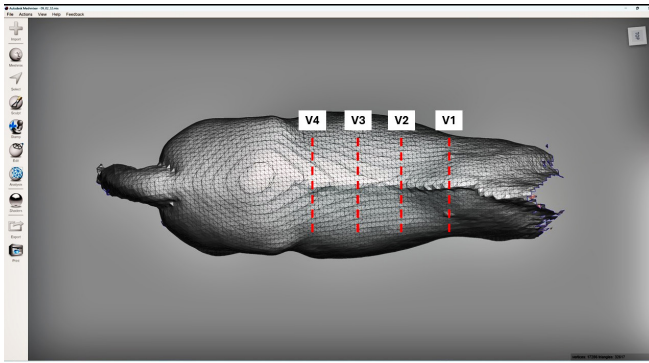


Figure 2: Same horse and file as in **Figure 1**, viewed from above, with the location of transverse plane cuts identified as V1 – caudal scapula; V2 – lowest point of the withers; V3 – midpoint between V2 and V4; and V4 – T18.

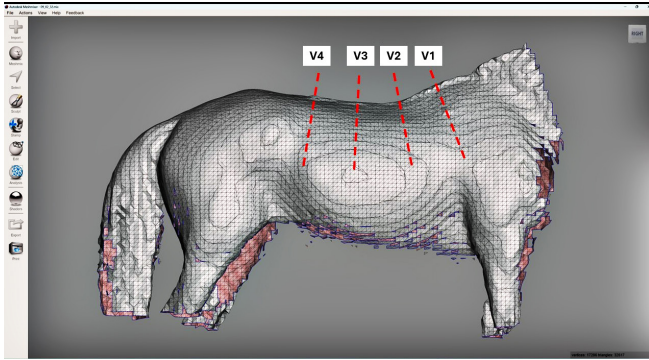


Figure 3: Same horse and file as in **Figure 1** and **Figure 2**, viewed from the right side, with the location and angulation of transverse plane cuts perpendicular to the back identified as V1 – caudal scapula; V2 – lowest point of the withers; V3 – midpoint between V2 and V4; and V4 – T18.

2.4. 3D Image Analysis

Each image was rotated to the sagittal view, and the Meshmixer software's slicing tool was used to divide the shell into four sections deep (V1 to V4). A transversely oriented plane cut was taken at the level of the marker of the left caudal scapula, perpendicular to the back surface (V1), and a second transverse plane cut was taken at the level of the marker at T18 (V4; also perpendicular to the back surface). Two further transverse cuts were made at the base of the withers, i.e., the lowest point/midpoint of the back (V2), and at the midpoint between V2 and V4 (V3), as shown in **Figure 2** and **Figure 3**. Each transverse cut section was saved as a .jpeg file and imported into ImageJ (National Institutes of Health, Bethesda, MD, USA) for determination of back transverse angle (**Figure 4**). The reliability of this approach has previously been reported [8].

In order to compare the measured angles with the ranges of gullet bar angles commonly provided by manufacturers of English saddles, images of gullet bars from six leading brands of English saddles were obtained either from manufacturers' websites or through saddlers. The brands selected were: 1) Kent & Masters, Thorowgood, and Fairfax (which all use the same gullet bar system); 2) Whitaker; 3) Wintec and Bates (which use the same gullet bar system); 4) Premier Equine; 5) GFS Monarch; and 6) Cavaletti. Gullet angles were

calculated in ImageJ. An example of the measurement of the angle of the GFS Monarch extra-wide gullet bar is shown in **Figure 5**.

2.5. Statistical Analysis

Normality of the distribution of data was investigated using the Shapiro–Wilk test. Data were found to approximate a normal distribution; therefore, a parametric approach was used. Comparisons between different stables for dressage and endurance were made using an unpaired t-test. Comparisons between back angles at different longitudinal positions (V1 to V4) within dressage or endurance were made using ANOVA and post-hoc Tukey's test. The relationship between back angles at different locations was investigated using Pearson's correlation. Data are presented as mean $\pm$ SD, and significance was set at $P < 0.05$.

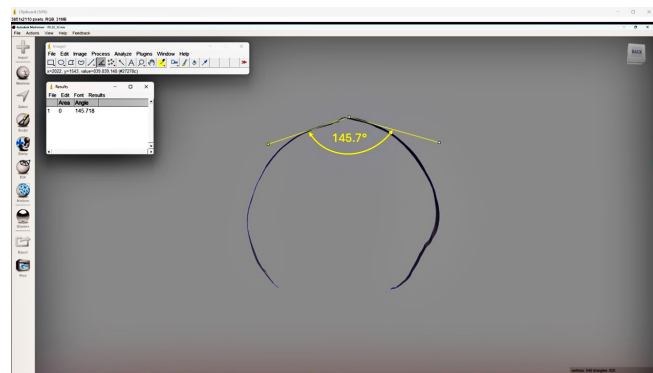


Figure 4: Same horse and file as in **Figure 1**, **Figure 2**, and **Figure 3**, with a transverse plane cut from Meshmixer at T18 (V4) exported as a .jpeg file, and back angle calculated in ImageJ. Image viewed from the cranial aspect. The image section is 20 mm wide (cranio-caudal distance).



Figure 5: Measurement of the angle (red line) of the GFS Monarch Extra-Wide gullet bar (pink) using ImageJ, indicating an angle of 100.3°.

3. Results

3.1. Back Angles

Successful scans were obtained from all horses. The number of repeat scans required due to scan failure, which was always caused by significant horse movement, was less than 1%. In both populations, the transverse back angle was narrowest at V1 and widest at V4, with the greatest change in angle between V1 and V2, followed by V2 and V3, and the smallest difference between V3 and V4 (**Figure 6**). The mean transverse back angle at V1 was $87 \pm 8^\circ$ for the endurance horse sample and $99 \pm 10^\circ$ for the dressage horse sample ($P < 0.0001$), and at V4 was $141 \pm 7^\circ$ (endurance) and $144 \pm 6^\circ$ (dressage) ($P < 0.0001$).

Overall, there was no significant difference in transverse angles at V1 to V4 between endurance stable 1 or 2, or dressage stable 1 and 2, and data for both endurance stables and both dressage stables were therefore combined for further analysis. For the endurance horses, ANOVA indicated a significant difference due to location (V1 to V4; $F = 85.5$, $P < 0.001$), and also for the dressage dataset (V1 to V4, $F = 83.7$, $P < 0.001$) (**Figure 6**).

3.2. Correlation Between Back Angles at Different Locations Along the Back

Correlation between back angles in endurance horse and dressage horse populations at V1, V2, V3, and V4 is shown in **Table 2**. In both the endurance and dressage samples, there was a strong correlation between the angle at V3 and V4, explaining around 60% of the variance. In neither sample was there a significant relationship between V1 and V4, and no relationship between V1 and V3 in dressage, with only a weak significant correlation for endurance. V2 and V3 and V2 and V4 were significantly correlated in the dressage sample but not in the endurance sample.

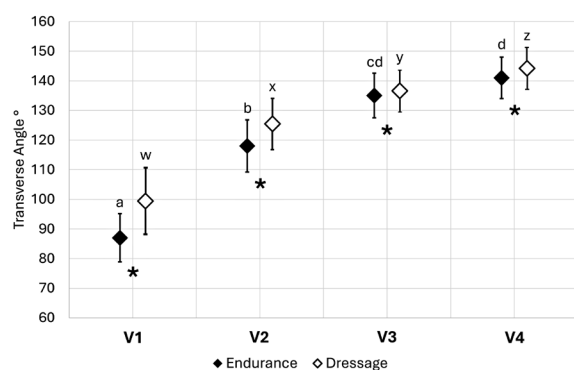


Figure 6: Transverse back angles perpendicular to the back surface at locations V1, V2, V3, and V4 in 23 endurance horses and 21 dressage horses. Mean $\pm$ SD. * indicates endurance significantly different from dressage at least $P < 0.0001$. Within groups (endurance or dressage), locations with different letters are all significantly different, at least $P < 0.0001$ for endurance. V3 versus V4 for endurance = ns ($P = 0.06$). For dressage, all locations were significantly different at least $P < 0.0001$, except V3 versus V4, $P = 0.013$.

3.3. Gullet Bar Angles Used by English Saddle Makers

The gullet bar angles from six English saddle manufacturers are shown in **Table 3**. The greatest variation in measured or manufacturer-reported gullet bar angles was for the larger gullet widths/sizes of medium wide up to 4XW (a range of $9\text{--}14^\circ$). Variation was considerably lower for narrow (5°), narrow/medium (8°), and medium (3°). The average increment between gullet bar sizes was $5 \pm 2^\circ$.

When the distribution of gullet bar angles from these six manufacturers, as opposed to how they refer to them in width fittings, is compared with the V1 angles of the endurance and dressage horse sample populations (**Figure 7**), it can be seen that both the endurance horse sample and dressage horse sample span the most common angle range of $80\text{--}110^\circ$. This further supports the use of the 3D light scanning approach in the present study.

Discussion

Previously, the reliability of 3D light scanning to estimate the cross-sectional area of the epaxial region of the thoracolumbar spine was reported using the same equipment and methodology as in the present paper [8]. 3D light scans of the thoracic epaxial region were taken from ten endurance horses, representing a sub-sample of horses in the present study. The total cross-sectional area of the combined epaxial musculature was calculated at the level of the scapula and T18. No significant differences were found between the two different assessors experienced in using the software ($P = 0.88$; ICC: 0.90 ; CIs: $0.82\text{--}0.95$). Intra-rater reliability for assessing thoracic profile and inter-rater reliability ICC values with experienced analysts were interpreted as good/excellent. These results suggest that 3D light scanning is an objective, noninvasive method to record size and symmetry of the epaxial region in horses and is likely to be more accurate and reliable than the use of flexicurves [8].

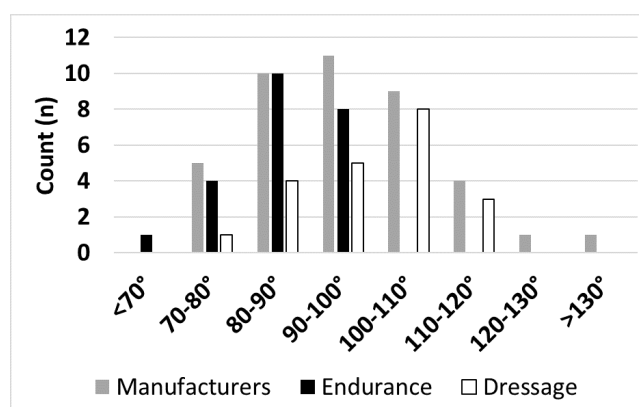


Figure 7: Distribution of gullet bar angles ($^\circ$) reported by manufacturers or calculated using ImageJ, where not reported by the manufacturer for six different brands of gullet bar system, compared with the distribution of V1 angles measured in endurance horses ($n = 23$) or dressage horses ($n = 21$).

Table 2: Pearson's correlation coefficient matrix for endurance (n = 23) and dressage samples (n = 21) at different back locations (V1, V2, V3, and V4).

Endurance (n = 23)					
Variable 1	Variable 2	r	r ²	df	P-value
V1	V2	0.38	0.14	21	ns
V1	V3	0.44	0.20	21	0.034
V1	V4	0.30	0.09	21	ns
V2	V3	0.30	0.09	21	ns
V2	V4	0.28	0.08	21	ns
V3	V4	0.76	0.57	21	P < 0.0001
Dressage (n = 21)					
Variable 1	Variable 2	r	r ²	df	P-value
V1	V2	0.37	0.14	19	ns
V1	V3	0.18	0.03	19	ns
V1	V4	0.03	0.00	19	ns
V2	V3	0.67	0.46	19	0.001
V2	V4	0.67	0.45	19	0.001
V3	V4	0.78	0.62	19	P < 0.0001

Table 3: Gullet bar angles (°) from six English saddle brands, either as reported by the manufacturer or measured from images.

Manufacturers classification	1 Kent & Masters / Thorowgood / Fairfax	2 Whitaker	3 Wintec / Bates	4 Premier Equine	5 GFS Monarch	6 Cavaletti	Mean	SD	%CV	Range	Increment
Narrow			75	77	72		75	2	3.3	5	
Narrow/ Medium	78		82	85	77	81	81	3	4.2	8	6
Medium	87	87	90	86		87	88	1	1.6	3	7
Medium Wide	91	97	92	91	83	88	90	5	5.3	14	3
Wide	95	103	95	97	91	93	96	4	4.1	12	5
Wide / Extra Wide	99						99				4
Extra Wide	106	107	100	102	96	103	103	4	3.9	11	3
Extra Wide / Extra Extra Wide	110						110				7
2XW	120	110	111			109	112	5	4.5	11	2
3XW			122		114		118	6	5.2	9	6
4XW			130		119		125	8	6.3	11	7

External methods for assessing the thoracic profile of horses, such as 3D scanning and flexicurves, do not reflect changes in the deeper musculature, such as the multifidus muscle [15], and ultrasound imaging is required for this [16]. The light scans collected for this study were not compared to a gold-standard ultrasound imaging method or to profiling with a flexicurve. However, collecting and analyzing these images using the techniques described in this study has been shown to be repeatable [8], and as such, the accuracy depends on the intrinsic accuracy of the Skanect system, which is almost certainly more objective than the flexicurve.

The narrowest transverse back angles were found at V1 and the widest angles at V4, which is unsurprising and consistent with conventional saddle design and flexicurve templates. Variance around the mean at each location was also similar, suggesting that there is a relationship between angles within a horse. Furthermore, it is unsurprising that the dressage horse population was found to be wider at all back locations measured, given the difference in body shape between the Arabian horses studied and commonly used in endurance, and the dressage horses, which were Warmblood, Warmblood X, and Hanoverian.

In both the endurance and dressage samples, there was a very strong correlation between the angle measured at V3 and V4, explaining around 60% of the variance in each. However, in contrast, there was no relationship between the angle at V1 and V4 in either the endurance or dressage samples. Conventionally, the gullet width of a saddle is measured at a location approximately three fingers behind the most caudal aspect of the scapula, which would equate to a position between V1 and V2 in the present study. While saddles come in a wide range of gullet angles and shapes, and gullet bars can be changed in many saddles, it is rare to find any saddle that allows adjustment towards the caudal aspect of the saddle. On the basis that, in this sample of horses, there was no evidence of a strong relationship between V1 and V3 or V1 and V4, the potential for saddle makers to provide saddles with varying caudal angles or caudal adjustment may be of interest.

Gullet sizing of English saddles, at least based on this sample of nine brands across six manufacturers, is not standardized. Some manufacturers use a range based on terms such as narrow, medium, wide, and extra wide, but without any specification of the angle, whereas others specify the angle of the gullet bar. However, the most common V1 angles measured in the present study reflect the most common gullet bar angles offered by manufacturers. Knowledge of back angles may potentially assist saddle manufacturers in saddle design and may also be relevant to professionals such as saddle fitters. 3D scanning also has the potential to highlight asymmetry in the area in which the saddle sits, which may again be relevant to saddle fitters, physiotherapists, and veterinary surgeons.

While static imaging of back dimensions may be informative, the "holy grail" is to be able to follow changes in back shape in horses ridden in saddles. Previously, we demonstrated that this is feasible in horses exercised at walk, trot, canter, and gallop on a treadmill without a rider or saddle [17]. More recently, equine back shape change has also been described in standing horses as well as in horses walking

and trotting in hand in an indoor barn under an array of high-speed cameras [18]. However, tracking back shape change in ridden horses at present appears to be extremely technically challenging.

4. Limitations

While 44 horses were scanned in this study, this is still a relatively small sample, and to describe populations accurately would require repeating with much larger numbers. For example, assuming a population of 800,000 horses in the UK, if 5% were Arabian, with a $\pm 5\%$ margin of error and a confidence level of 95%, a sample of ~380 horses would be required. Furthermore, this study did not attempt to validate the accuracy of 3D light scanning against "templating" with flexible rulers, although it can be reasonably anticipated that the 3D approach will be more accurate and reproducible.

5. Conclusions

In conclusion, the present study has demonstrated that thoracolumbar angle increases from the caudal aspect of the shoulder to T18 in samples of both endurance and dressage horses, with the greatest increase from V1 (caudal shoulder) to V2 (lowest point of the withers), and that dressage horses were significantly wider in this region at all locations measured. Furthermore, there was no or weak correlation between V1–V2 angles, where saddles are conventionally fitted, and thoracolumbar angles in the caudal region where the saddle would sit (V3–V4). Finally, while there is little consistency in what gullet angle a "medium" gullet bar would actually be, the range of angles measured at the shoulder in the present study does reflect the most common gullet sizes that are offered by six manufacturers of English saddles. Further studies might investigate the accuracy and repeatability of 3D light scanning apps using mobile phone-based front-facing or rear-facing LiDAR against flexicurve templates as an aid to saddle design, saddle manufacturing, and saddle fitting.

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Authors' Contributions

DM conceived the study, collected the data, analyzed the data, and wrote the manuscript.

Data Availability

Requests to access 3D scans for further collaborative analysis will be considered favorably on a case-by-case basis.

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Conflicts of Interest

David Marlin was compensated financially for his time by Ergon Equine Ltd to conduct this study, analyze the data, and prepare the manuscript.

Ethical Approval

Ethical approval was not required.

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With Great Power Comes Great Responsibility: Equestrian Coaches, the Real 'Influencers' Within the Equestrian Community, Share Their Perspectives on a Sustainable Future

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Abstract

Background and Aims: The sustainability of equestrianism, as a sport and as a way of life, is currently in jeopardy. This is primarily due to the growing societal concerns regarding equine welfare in performance sport and the associated unethical human behavior. Expanding upon a growing body of research and action within the sector, this study looks to those who stand in the middle of the arena to shed light on the antecedents and consequences of poor horsemanship and to explore how the industry as a whole can work together to ensure a sustainable future. **Materials and Methods:** Sixteen British Horse Society Fellows and/or United Kingdom Coaching Certificate Level 4 coaches were recruited for this qualitative study. Participants took part in guided roundtable discussions, which were audio/video recorded, transcribed, and then analyzed using thematic analysis. **Results:** Three high-order themes were identified. First, Individual Responsibilities in Equestrian Sport, with subthemes of human behavior change, advocating for the horse, and the coach as an ambassador for best practice. Second, Comprehensive Equestrian Coach Education, with subthemes of the role of mentorship, vicarious and continual learning, technical and coaching competencies, and formal coach education. Third, Collective Responsibilities in Equestrian Sport, with subthemes of horsemanship education, challenges and opportunities for sustainability, and cohesive practice for horse welfare. **Conclusion:** Coaches offer a vital source of counsel and are key influencers within the equestrian community and, therefore, should be considered instrumental in creating a sustainable future for equestrian sport from the inside out. To this end, equestrian coach education must ensure that, alongside technical and coaching competencies, the ability to demonstrate and teach the skills and values that provide psychological safety for humans involved in equestrianism is also taught and assessed.

Keywords

Equestrian coaching; coach–athlete relationship; human–horse relationship; equine welfare; equestrian sustainability; social license to operate

1. Introduction

Human motivations, decision-making, and behavioral proclivities, both at an organizational and individual level, are central to the challenges currently faced by equestrian sport

[1,2]. With increasing exposure and a dominant narrative across social media and national news outlets of harmful practices that negatively impact equine welfare, the inherent challenges within equestrian sport must now contend with public opinion and a social license to operate, as well

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as, at times, the somewhat conflicted concerns of the wider equestrian community [3,4]. As a result, steps have been taken by a variety of professional sport organizations worldwide to rectify the public's disdain [4], with some countries clearly taking a more proactive stance than others [5]. Over-archingly, as the worldwide governing body for equestrian sport, Fédération Equestre Internationale (FEI) has commissioned an independent task force to create a policy that aims to mitigate these challenges. The strategy, appropriately entitled 'A Good Life for Horses,' outlines, among others, key objectives for its members, which are to proactively promote and maintain good welfare and to ensure that equine involvement in sport does not compromise welfare [6]. The latter objective, given the high-risk demands of many equestrian sports, is perhaps a rather naive or certainly optimistic ambition. As Furtado *et al.*'s research observed, significant challenges in equine welfare arise from "conflicts between competition demands and the basic needs of the horse" [7]. This brings into question whether the life of an equine athlete can ever truly constitute living their best life [5]. Nevertheless, the intention and actions taken here are a positive start and speak to a worldwide recognition that if considerable changes are not brought about soon, equestrian sport may be on borrowed time [8]. The contextual reality, however, is quite saddening: this sudden impetus from key professional sport governing bodies to improve equine welfare in equestrian sport has stemmed purely from a surge in negative societal perceptions that have brought poor practices into question and, therefore, prompted the desire to convey practices that reflect society's values [3,9]. It seems only when the future of the sport is threatened do those organizations begin to question long-held accepted practices and take some accountability for human behaviors that have historically gone unpunished, or worse, have been readily condoned and, oftentimes, both rewarded and celebrated in competition arenas [10,11].

In contrast, equine welfare organizations worldwide have consistently advocated for more stringent policing of the use of horses in sport, in work environments, and in the day-to-day welfare of all equids, both wild and domesticated. Indeed, in a recent white paper composed by several organizations and led by Eurogroup for Animals, the authors called for European animal welfare legislation to ensure consistent protection for equids across their varied living and/or working contexts, while also addressing their species-specific needs [12]. Interestingly, in 2020, Blattner [13] posed the question of whether 'work' (one could argue that being an equine athlete is a form of job) can be instrumentally good and/or intrinsically valuable to animals, and equally therefore, should they have a right to work as humans do and, in turn, be protected by those rights? The work itself is considered instrumentally good if it provides access to resources that the animal needs for a good life and if it offers the deserved recognition, respect, and appreciation of their unique contribution. Blattner [13] also argued that some emerging evidence (see [14–18]) suggests that, for some animals, work could be intrinsically valuable, providing them with "challenge, focus, tasks, and relationships of labor that nurture mutual respect, characterized by reciprocity, appreciation, satisfaction, and opportunities for self- and co-realization." Indeed, many of these aforementioned characteristics were also identified by Tufton and Jowett [19] as key elements of

quality human–horse relationships. This offers scope for further inquiry in equestrian sport, particularly as equine welfare doctrines are now advocating not only for the avoidance of negative welfare states but also for the promotion of positive welfare states [6,12,20].

One of the key challenges, however, when addressing welfare in equestrian sport is defining and establishing what factors contribute to good equine welfare [4,21]. To this end, Williams *et al.* [5] conducted a Delphi study to identify key stakeholders' perspectives and reported that young horse management, training management, health status management, competition management, and the human–horse relationship were considered essential factors. This highlights that, with the exception of the horse itself, the most critical common denominator across all of these essential equine welfare factors is the decision-makers, the human beings responsible for them. Indeed, several researchers have called for a stronger focus on human behavior change in future equestrian research to promote improved equine welfare [1,2,22,23]. While it could be tempting to assume that poor practice and the decisions that lead to detrimental welfare consequences for the horse are born entirely out of ignorance or lack of knowledge, it would be negligent to ignore factors such as the influence of significant others, internally driven pressures, and the cultural landscape within which participation in equestrian sport is embedded. It could be construed that these behaviorally influential factors have the power to supersede an individual's implicit knowledge and override their personal moral and ethical values [24]. After all, it is unlikely that most of the high-profile incidents of poor horsemanship in elite sport can be explained away as a lack of knowledge; the underlying motivations that led to those behaviors are more likely a result of human ego and overzealous ambition [9]. Therefore, it could be argued that personal motivations and sociocultural influences are key explanatory factors for some of the poor horsemanship practices plaguing the equestrian industry. What is of the utmost importance, however, in order to effect real change, is to truly understand the root causes (i.e., attitudes, intentions, motivations, external influences) and to investigate the conditions that may lead to unethical behavior in equestrian sport [23]. At present, a great deal of judgment is being passed on individual cases of unethical horsemanship without any understanding paid to the causal conditions that may have led to and facilitated these behaviors, and without consideration of the potential mental health consequences that may follow [25].

The sampling profile of the 'stakeholder' participants in Williams *et al.*'s study [5] was (quite rightly) designed to represent expertise across equestrian disciplines. However, a stakeholder is anyone "who can affect a decision or is affected by an action" [26], and when investigating human behavior with regard to equine welfare and a sustainable future for equestrian sport, there are other stakeholders' perspectives and experiences to consider. Equestrian coaches are key stakeholders, as beyond the knowledge they provide for the improvement of performance outcomes, they also bear a significant responsibility in shaping individuals' attitudes, beliefs, and experiences, both human and equine [27–29]. Therefore, through their interactions with human–horse partnerships across participation contexts on a daily basis,

one could argue that equestrian coaches, to use an idiom from the current generation, are the true 'influencers' within the equestrian community [30–32]. Indeed, an influencer is simply defined as someone who affects or changes the way that other people behave [33]. However, despite the significance of their role and the uniqueness of this coaching context, there is minimal academic research on equestrian coaches and their coaching practice. Therefore, through the use of roundtable discussions, this research seeks to gauge equestrian coaches' perspectives on the future and sustainability of equestrian sport through the lens of the coach's role within human–horse relationships.

2. Materials and Methods

2.1. Ethical Considerations

Ethical approval was granted by Buckinghamshire New University prior to the commencement of data collection, and this study followed the guidelines of the Declaration of Helsinki. Participants were fully informed of the aims of the study, asked to provide their consent, and advised that they could withdraw from the study at any time up until the point of data analysis. Participants were advised in advance that the roundtable discussions would be audio- and video-recorded; however, only the transcript would be used and retained for data analysis, and the video/audio files would be destroyed. Following completion of the roundtable discussion, participants were asked to preserve the confidentiality of all attendees' contributions to the discussion, and were also given a copy of the transcript and a period of two weeks to review and request any amendments. All participants' names were anonymized through the use of randomly allocated letters, as well as the names of any individuals discussed. The names of national equestrian coaching organizations have been included, as they were pertinent to the discussions that unfolded.

2.2. Design

This qualitative study aimed to explore coaches' perspectives on sustainability in equestrian sport through the lens of the coach's role within human–horse relationships. Participants were invited to engage in a guided roundtable discussion, and the data obtained were analyzed using thematic analysis.

2.3. Participants

Participants were recruited for this study using a specified sample criterion, whereby prospective participants had to be a Fellow of the British Horse Society (BHS) and/or hold a Level 4 United Kingdom Coaching Certificate (UKCC). These are the highest level of coaching qualifications in equestrian sport in the UK. All individuals who met the aforementioned criteria and who were listed on the BHS and UKCC websites with publicly available contact details were sent information about the study via email. At the time of approach, the total number of active coaches who held the qualifications was 57 (BHS Fellow) and 40 (UKCC Level 4), of which 55 (BHS) and 31 (UKCC) were approached via email, as only these individuals' contact information was published on the respective websites. Fourteen participants (6 female, 8 male) took part across four roundtable discussions. In addition, two further female participants provided responses to the questions in writing. This was decided in the spirit of inclusivity, as these participants did not feel confident using the necessary

technology to join the roundtable discussion via an online platform [34]. However, the researchers felt the participants' wealth of experience and knowledge should not be excluded from this research due to these perceived challenges, so an amendment was made to the ethics approval application to accommodate this change. Similarly, those who volunteered but could not take part due to logistical reasons were offered this option; however, there were no further written responses. The date of obtaining their qualification for the participants as BHS Fellows ranged from 1970 to 2022, and for UKCC Level 4 ranged from 2017 to 2020. Interestingly, at the time of approach, the relatively equal split of male and female participants was reflective of the female-to-male ratio of active BHS Fellows (29 females and 28 males). However, the female-to-male ratio for UKCC Level 4 coaches was very different, with 34 females and only 6 males holding the qualification. Only one female participant held both of these specific qualifications. Collectively, participants represented coaching practice across a range of equestrian pursuits and, individually, most held member body affiliations with either British Eventing, British Dressage, or British Showjumping. Likewise, many provided coaching services under the umbrella of organizations such as the Association of British Riding Schools, The Pony Club, and the Riding for the Disabled, and/or operated independently as freelance coaches.

2.4. Materials

The four roundtable discussions took place via the Microsoft Teams meeting platform and were facilitated by the lead researcher. The decision was made to conduct the roundtable discussions online for logistical reasons; participants were located across the United Kingdom and some internationally, with varying schedules, so the most practical option was an online setting. While historically it has been argued that for qualitative methods such as this, conducting the roundtable discussions in person can result in more in-depth data, a review article suggested that since the recent Covid-19 pandemic, individuals have become more acclimatized to online interaction and the associated etiquette for group discussion [35]. Each roundtable included a maximum of four participants, which was a conscious decision to ensure depth of discussion across the outlined topics. In keeping with this, the enhanced functionality of online platforms can support the researcher in ensuring that everyone has the opportunity to share their perspectives in a more equitable way, as well as facilitating the optimization of the data collection process through the automated provision of audio/video recording and transcription [36]. The Microsoft Teams platform generated the transcript, which was then downloaded to Microsoft Word, where the lead researcher reviewed it, corrected any errors, and anonymized the data for analysis.

The findings reported in this paper are part of a wider study that sought to explore the role of the coach in developing and maintaining sustainable human–horse relationships in equestrian sport and activities. The questions posed during the roundtable discussion explored topics such as humans' motivations and goals for their equestrian partnerships, relational dynamics across the triad, and how formal and informal coach education informs coaching practices. However, the ensuing discussions frequently evolved beyond this to include the current wider challenges facing the equestrian industry. It was always anticipated that the findings

would be reported across two papers; however, the way the content was ultimately attributed to each paper is addressed in the Data Analysis section of this Methodology.

2.5. Procedure

Upon joining their respective roundtable discussion, participants were briefed again on the purpose of the study and thanked for voluntarily giving up their time. Participants were reminded that the roundtable discussion would be video/audio recorded, but only the transcription would be used for the data analysis, and that the video/audio files would be destroyed. They were also advised that they would have the opportunity to review the transcript and of their right to withdraw. Each roundtable discussion lasted approximately two hours, with all participants contributing significantly to the discussion. Once the discussion was concluded, the participants were thanked for their contribution, asked to preserve the confidentiality of the discussion, and advised that they would be informed when the study was published.

2.6. Data Analysis

Grounded in a constructivist ontology (i.e., beliefs reflect a shared reality, but individual interpretations of reality differ) and an interpretivist epistemology (i.e., understanding how individuals create meaning and knowledge through their experiences), the data were analyzed using Braun and Clarke's reflexive thematic analysis process [37]. Following anonymization and collation of the four transcripts, the researchers maintained the original six stages of Braun and Clarke's thematic analysis process [38], which included in-depth familiarization with the data, development of initial coding and observations across all transcripts, exploration of low-order themes both within and across the four roundtable discussions, refinement of low-order themes and confirmation across transcripts, grouping of low-order themes into newly created high-order themes, and compilation of the report. While Braun and Clarke [39] asserted that "A research team is not required or even desirable for quality" in reflexive thematic analysis, mindful of their own research 'lens,' the lead researcher made a conscious decision to bring in two additional researchers to support the analysis process. Both individuals have significant involvement in equestrian sport and are experienced sport psychology researchers, and each brought a unique perspective that greatly enhanced the methodological rigor of the analysis process [40]. Likewise, recognizing the importance of one's own personal reflexivity and interpretive agency in reflexive thematic analysis [41], each researcher reviewed the transcripts independently and generated their own initial coding and low-order themes before meeting to share their interpretations and critically compare their low-order themes. Following a number of discussions and further independent reviews, the final low-order and high-order themes were identified. The combined transcripts totaled over 65,000 words; therefore, given the complexities of roundtable discussions, the thematic analysis was conducted on the data as a whole, producing twenty-two low-order themes, which were then organized into six high-order themes. Two clear narratives were evident across the findings, reflecting two distinct yet related areas of focus in terms of sustainability. The first narrative pertained to the role the coach plays at a micro level in developing and maintaining sustainable quality relationships within the coach-athlete-horse triad. These findings are represented

by twelve low-order themes across three high-order themes and, as previously asserted, are reported in a separate paper. The second narrative explored how the coaches perceived their role at a macro level and the wider context of sustainability in equestrian sport, how their coach education informed their practice, and the role of coach education in sustaining equestrian sport. These findings are represented by ten low-order themes across three high-order themes and are reported in this paper.

3. Results and Discussion

This research sought to explore coaches' perspectives on sustainability in equestrian sport. Through qualitative analysis of roundtable discussions, three high-order themes were identified, reflecting the requisites they perceived as essential for sustainability: individual responsibilities in equestrian sport, comprehensive equestrian coach education, and collective responsibilities in equestrian sport. A summary of the high-order and low-order themes is detailed in Table 1.

3.1. Individual Responsibilities in Equestrian Sport

This high-order theme focuses on elements that all equestrians should consciously reflect on and prioritize in their engagement within equestrianism at an individual level. This is illustrated through the low-order themes of: human behavior change, advocating for the horse, and the coach as an ambassador for best practice.

One of the most poignant comments made during the roundtable discussions came from Coach C: "I love my sport, but I don't love the people in it." This was a sad reflection of the multitude of concerns raised regarding human behavior within the equestrian industry. However, an equally salient observation was made by Coach D when describing having to address concerns about a young rider's weight gain with their parent: "I said, well, that's what I'm getting at, it's not the weight. There's a reason for the weight," thus acknowledging the underlying psychological factors and/or lifestyle changes which may have led to the rider's weight gain. Indeed, taking steps to understand and resolve the root cause of behavior is a far more effective way of achieving positive behavior change, as opposed to only addressing the behavior itself [23]. Over the course of the discussions, several internal and external factors were identified that led to human behaviors that were often detrimental to both their own and, most pertinently, to their horses' experiences. Coach J identified that the ability to regulate emotions, maintain objectivity, and be flexible in one's approach were considered key factors in successful human-horse interaction:

"So when the rider runs into problems, they're clear in their mindset about how to manage different situations and to remain controlled in their emotions and mindset so that they can explain things to the horse in a different way or use a different exercise as necessary."

However, in reality, self and others' expectations and the conditions of a competitive environment can heighten unhelpful thoughts, emotions, and behaviors in the human, which in turn can influence their decision-making and interaction with the horse [42], who as Coach C observed, then gets the blame: "They can't seem to get their head around the idea that if something goes wrong they need to look at themselves rather than look at the horse." Therefore, as Coach M asserted: "You

have to work on yourself first and that self-recognition," which highlights the need for coaches to encourage more objective self-awareness in their athletes [43]. Indeed, encouraging a more evaluative appraisal by athletes of their actual versus ideal self as a competitor can support addressing the steps required to gain perspective on the discrepancy between those two selves [44], and temper the human's emotions, ambitions, and expectations for the speed of progress in their performance. Interestingly, this sparked wider discussions of social comparison in equestrian sport and athletes' concerns around appearing 'competent' in competition, where the 'finished product' seems to be valued over 'work in progress,' leaving athletes reluctant to show a work in progress for fear of being perceived as incompetent. Coach N offered an eloquent analogy of this, comparing it to an artist who covers their easel while they are creating their art:

"They're trying to show the finished product at the start of the process because they don't trust their talent and their technique, or they don't have a process. So, then they've fouled everything up, but that's nothing to do with their riding skills, and it's purely to do with their inherent artistic temperament. And that's something that they can change through really focusing on it and divorcing it from the riding skills."

This combination of ego, vulnerability, and lack of trust in their own competence can have a negative impact on the horse's learning, development, and welfare, and participants consistently advocated against forcing the appearance of a 'finished product' in competition environments, when fundamentals are not yet in place. Despite this, the prevalence of this ego-driven, goal-oriented behavior at the cost of equine welfare remains a grave issue across equestrian performance disciplines, particularly where it goes unpunished [10,11]. This highlights the need for a cultural shift in what is valued and/or required at varying levels of competition to reflect a more compassionate and learned approach to horsemanship that champions the fundamentals and the 'work in progress' [45].

Indeed, participants consistently emphasized the importance of recognizing that engaging in equestrian sport serves the human's ambitions alone, and that horses have no autonomy over their participation. As Coach L observed, "Our sport is a very unique sport because it involves another living sentient being who is not a volunteer, and we have to constantly remind ourselves that the horse did not ask to be ridden." Therefore, participants advocated that any actions related to the pursuit of these training and competitive goals should be horse-centered, meaning humans should endeavor to have a more comprehensive knowledge and understanding of the horse's learning processes and perceptual differences, and, without compromise, prioritize horse welfare ahead of any personal ambition [46]. Several discussions focused on a specific area of concern: the importance of training the horse within the realms of their physical and mental capability. Coach B recognized the coach's role in ensuring this: "I think as a coach one of the parts where we have to lead them is that

the aims and the goals are suitable to the horse that they sit on." Equally, further discussion highlighted the need for consideration of rider capability, their stage of development, and indeed personality and temperament when matching human-horse partnerships [47].

One of the most prevalent messages with regard to advocating for the horse was how they emphasized the value of listening to the horse's feedback, not just from a welfare perspective but in recognizing and admiring their strengths and intuitions, and that this is how the human's next action should always be informed:

"We need to listen to the horse. We need to learn to see the signs in the horse, the language that the horse speaks back to us, because unlike human beings, where we sometimes can hide our feelings behind a front, horses don't hide their feelings; they have no reason, they are not calculated enough. Feelings, they will tell you how they are, and then what they think, how they react, what has happened to them.... we need to access those and react to those and then make a plan." (Coach B)

This supports the need for humans to recognize the horse as an equal partner, the necessary reciprocal nature of the interaction, and focus their attention on what the horse is communicating, which could ultimately benefit both welfare and performance [48]. As Coach K observed: "What makes those partnerships and it's just horses are so intuitive to the end user, the individual they're with." Therefore, if you are willing to listen and learn, the horse will show you who you are and how you need to be to earn their trust and positive engagement [49]. Similarly, Coach Q conveyed the importance of using that feedback, encouraging athletes to be inquisitive and to continually reflect: "The 'why' is absolutely fundamental to the coaching, and I think that is how you inspire people." Likewise, Coach R asserted how, as a coach, you must demonstrate the desire and action to be the best you can for your horses and motivate those you teach to do the same:

"We need to be the guy that inspires that sort of enthusiasm to learn, that sort of curiosity to find out more about what we do, why we do it, to find out more about the horse, to find out more about why the horse gets motivated by certain sorts of skills that we have and why."

This profound sense of responsibility for the horse was evident across all participants, not only to exhibit these desirable behaviors but to cultivate it in their athletes [50]. As Coach N asserted: "My philosophy is empowering the rider for the good of the horse." This empowerment is facilitated, participants believed, through open reciprocal communication between coach and athlete, developing psychophysiological confidence in human and horse, and as Coach B described, the flexibility as a coach to be what the partnership needs you to be for them at any one time:

"You need to be able to change yourself and move yourself into different roles depending on the people that you're working with and the horses that you're working with, and how you then deal with those situations."

Table 1: Thematic analysis of coaches' perspectives on sustainability in equestrian sport.

High-order themes	Low-order themes	Example quotes
Individual responsibilities in equestrian sport	Human behavior change	<i>"Always look for the fault in the mind of the rider, not in the body of the horse, and always look for the result and the solution in the mind of the rider and not in the body of the horse"</i> – Coach C
	Advocating for the horse	<i>"The biggest problem with equestrian sport, the difference between that and any other sport is if a beginner gets it wrong in another sport, the apparatus doesn't suffer because it's not living and sentient"</i> – Coach L
	The coach as an ambassador for best practice	<i>"I feel if you, as a coach, have done your job absolutely right and so on, then that person that you have developed should be able to manage themselves"</i> – Coach B
Comprehensive equestrian coach education	Role of mentorship	<i>"It's our role to act as mentors and provide guidance because we can have these conversations, particularly around welfare and performance"</i> – Coach M
	Vicarious and continual learning	<i>"As an industry, we don't encourage people to look outside our own industry enough"</i> – Coach N
	Technical & coaching competencies	<i>"It used to be only really on the technical years ago, but now the coaching skills do get quite a strong consideration, but not enough in many ways"</i> – Coach N
	Formal qualifications	<i>"They're learning how to coach, but they actually don't know what to coach"</i> – Coach Q
Collective responsibilities in equestrian sport	Horsemanship education	<i>"The scales of training are gone through in such a way that it ignores the mental state of the horse"</i> – Coach P
	Addressing challenges and opportunities for sustainability	<i>"There is a danger that if we assume that science and rationally proving things is going to win people over, we may be bitterly disappointed"</i> – Coach Q
	Cohesive practice for horse welfare	<i>"What drives people to change if they're seeing success without needing to change that mindset?"</i> – Coach F

This demonstrates an emotionally intelligent approach, which emulates the characteristics previously advocated by participants for athletes to adopt when working with horses, such as self-awareness, self-regulation, and empathy [19]. Moreover, further characteristics were identified as essential for an equestrian coach, such as having the gumption to challenge poor practice or poor behavior, and a sense of openness and compassion for exploring new ways of working with horses that prioritize welfare above all else. All of these values, characteristics, and attitudes fostered by the participants are a product of a lifetime of experience and education, which has shaped the coaches that they have become today. Interestingly, however, not all of their own personal experiences when receiving coaching had been so positive:

"I had some early experiences actually in the equestrian world at what was then a very, very famous eventing training yard, probably the most famous eventing training yard, but it was a very brutal place to be and definitely something that's gone on to shape me as a coach. Similar to you two, I think, in not wanting to be that, not wanting people to have the experiences that I had, not wanting to be that person that I experienced." (Coach Q)

Likewise, Coach J asserted: *"...and I also vowed from the early days I was never gonna allow anybody to ever feel how I felt in those early days,"* highlighting that negative experiences have also shaped their coaching philosophies and applied practice. While these examples ultimately reflect a positive response to adversity for these individuals, this demonstrates the prevalence of negative coaching behaviors and the psychological impact they have on equestrians, which may play a key role in the beliefs and motivations for unethical behav-

iors seen in equestrian sport. In contrast to the participant examples, the consequences of poor coaching practice may legitimize (in the eye of the beholder) future poor behaviors, with equestrians believing that if their coach, in a position of power and authority, deems a negative behavior acceptable, then it must be right or justified and therefore may continue such behavior in their own practice, despite its detriment to horse or human wellbeing [51]. Indeed, an authentic behavioral culture change is generated from within, not dictated from the outside; therefore, the coaches' advocacy for the prioritization of horse welfare must coincide with a more compassionate, mindful approach and a duty of care for the human athletes under their charge. As a result, this could have a positive knock-on effect for horse welfare as well, where, for example, athletes are given the opportunity to reflect on their motivations for unethical behavior in a safe space and explore alternative behaviors or responses [52]. As key influencers, this responsibility as coaches for the cultural legacy of equestrian practice is not insignificant and extends beyond general welfare knowledge and understanding to demonstrating and instilling the values of self-awareness, emotion regulation, and compassion for horse and human in training and performance. The question remains, however, as to whether these values, or indeed how to teach these values, truly feature in formal equestrian coach education, or whether these values are mistakenly assumed to be intrinsically present in all coaching candidates.

3.2. Comprehensive Equestrian Coach Education

This high-order theme comprises low-order themes that represent a breadth of factors discussed that inform and

influence the quality of coaching practice, namely the role of mentorship, vicarious and continual learning, technical and coaching competencies, and formal qualifications.

All participants spoke reflectively about key individuals who had influenced both their values and their pursuit of equestrian coaching as a career [53]. Most notably, they discussed mentors who had emboldened them to pursue formal coach education: *"It encouraged me to go down the BHS route, which I'm still very passionate about and even from that age, I knew that I wanted to eventually become a BHS Fellow"* (Coach L), and who had influenced the evolution of their horsemanship journeys, highlighting for example, the benefits of delayed specialization:

"...he said you're going to go and develop your horsemanship skills. He said you're going to learn about three-day eventing. You're going to learn about dressage, you're going to learn about racing, you're going to learn about hunting, you're going to learn about show jumping. Then you decide." (Coach C)

Several participants spoke of their own roles as mentors and the need to provide neophyte coaches with a psychologically safe space to objectively evaluate their coaching practice [54,55]. Other participants described experiences in which their mentors had provided honest feedback:

"They've given me hard truths, and I've been a bit 'ugh,' but you know what, I really respected them and admired them for that, and they know me well enough, and I know them. They might not always tell me what I want to hear, but I really respect what they say, and they listen." (Coach J)

Coach M also reflected that they felt they had missed out on and would have personally benefited from a trusted confidante to: *"Help them have those uncomfortable conversations about welfare, that for me would be what I would have liked."* Participants also told stories in which mentors had demonstrated key traits associated with high performance, such as openness to experience [56], embracing every opportunity to gain new knowledge from a variety of sources: *"He, in many ways was, I think, ahead of his time, but really did think outside the box in that sort of way about the learning"* (Coach B). Indeed, the value placed upon vicarious and continual learning was prevalent across all of the roundtable discussions [57]. For example, participants observed that equestrian coaches' openness and willingness to engage in training days were challenging within the industry, but they strongly advocated for the importance of collaboration and coming together in person to share experiences and knowledge without the pressure of assessment or continual professional development (CPD). Equally, they warned of the danger of segregation within the industry: *"The thing that I really miss is cohesion, and I think it's probably the hardest thing for the equestrian world to attain, because everybody has their factions, everybody has their silos"* (Coach F), and suggested that more opportunities to bring coaches from different specialisms together to share their philosophies and processes in equestrian practice would be invaluable for positive coach development [58].

Coach B observed the heightened complexity and responsibility for equestrian coaches: *"If we don't coach people to ride and look after the horse in the correct way, we are compromising the welfare of the horse, and that's why, to me, of all the sports in the*

world, equestrian sports needs coach education." However, one of the most significant challenges participants observed within the industry was the dangerous assumption that if you are a talented/accomplished rider, you will be a good coach. While this misguided assumption of 'competent athlete = competent coach' is not unique to the equestrian industry, concerns were raised that individuals who are unqualified and unregulated as coaches were still gaining coaching opportunities due to their successes as a rider and not as a coach. For example, Coach L commented:

"Somebody gets a little bit of street cred for training probably one horse through to Prix St. George or to Foxhunter level or something like that, which isn't a high level, and then they suddenly become a coach, and everybody flocks to them and with disastrous results."

Equally, it was also acknowledged that it can be challenging for 'gifted' riders to be able to explain or teach skills that come so naturally to them, as Coach C stated: *"This is one of the difficult things in coaching. You see, that's what we can't do, is teach 'feel'."* Concerns were also raised that even qualified coaches may adapt their coaching style to cover up their own inadequacies: *"That's the challenge, I think people look at the sort of 'set up and stand back' model and the 'feedback' model, and they utilize that for their lack of technical knowledge"* (Coach F). It therefore appears that more stringent policing and more comprehensive formal coach education are needed [59]. Indeed, all participants agreed that there is an inherent need for equestrian coaches to develop both technical and coaching competencies, and this led to passionate discussions on the current formal qualification provisions available in UK equestrian sport.

As long-term beneficiaries of the UK equestrian coach education system(s), many of the participants were quick to advocate the merits of both the BHS and the UKCC routes to qualification, and indeed, Coach D affirmed this through her experience as a coach educator:

"The coaches I'm helping and worldwide...going into all these different countries, you know, they are very open to listen and to do what they can. But, my goodness, they're a long way behind us, you know, on the horse welfare and well-being is way behind us."

However, key distinctions were made between the two qualification pathways in terms of their respective strengths, and it was suggested that while the BHS focuses primarily on technical competency and horse husbandry, the introduction of the UKCC has provided more understanding of the coaching process, with a greater focus on coaching people. As Coach D advocated: *"This would work much more so if we could merge those two, as they are missing out if they don't have both educations."* Indeed, several of the participants were dual-accredited as BHS Instructors and UKCC Level 4 coaches and reported that they had expanded their knowledge and applied practice by engaging in both educational routes. Furthermore, participants also shared their frustrations with the complexity of multiple qualifications and routes across different equestrian sports, and the limitations that this creates for their coaching practice:

"I've had people from British Eventing speak to me, but I don't have their qualifications, so then in theory, I've got to step across and do theirs to then work with some of the riders that I'm already working

with, but I'm just not doing it under their umbrella, and I just think, why is it so complex?" (Coach F)

The overarching consensus was that the equestrian coach qualification system would benefit from universalization and simplification:

"Certain governing bodies will only accept qualifications because it's their qualification, and it's so just thinking why?? You know the equestrian world is actually, you know, we are a small broad church, we're not a big industry in terms of coaching as a whole, there's lots of different facets to that, and I would just love to see that journey for that young person coming through much easier cause right now it's really very complicated." (Coach K)

Indeed, the early specialization of qualifications according to equestrian discipline also raised further concerns amongst participants regarding the constraints this may have on coach education and, in turn, coaches' all-round horsemanship knowledge and experience: *"We mustn't lose the fact that we're on horses that are designed to be outside, and we risk producing coaches who have never taught outside"* (Coach P). Similarly, Coach H observed the trickle-down psychological effect of this on their clients:

"Coaches that don't have a huge amount, as the next generation are coming through, they've not ridden outside themselves. I often say to my students, you know, I was brought up cantering across fields, and I didn't have an arena, and you know, jumping little hay bales and things, and you learn your seat and your balance, and you learn to be brave and confident like that. And I always say, particularly to my Pony Club children, I say you know, you won't get brave, and you won't get confident in an arena, you have to go outside."

Despite these challenges, many participants asserted that positive changes were happening at all levels of qualification within the equestrian industry that promote competencies which align with horse welfare values. For example, Coach D stated that for the BHSI qualification: *"We have insisted that no matter what level riders they are and even if they come in as top riders to take the exam, the first section is that they go in an open field with a group of at least four riders and they ride a horse and then they discuss the needs of the horse."* This underscores the positive impact of a comprehensive coach education on horsemanship practice and demonstrates a horse-centered, welfare-first approach to equestrian sport as the priority [6]. However, a broader focus on equestrian coaches' holistic responsibility for the psychological safety of the humans in their care may further support this cause [52].

3.3. Collective Responsibilities in Equestrian Sport

This high-order theme encapsulates the areas of discussion that explored some of the 'big-picture' topics that affect the equestrian industry as a whole. These topics have been identified through the low-order themes of horsemanship education, addressing challenges and opportunities for sustainability, and cohesive practice for horse welfare.

The growing deficit of all-around horsemanship education in the equestrian community as a whole was a grave concern for participants, and this prompted interesting discussions of why and how this has come to be. For example, participants explored contributing factors such as individuals'

perceptions of risk [60] and the impact of technological advances and influential others on individual behavior [61]. It was suggested that, alongside the false sense of security of staying in the 'safety' of the riding arena as previously discussed, participants argued that certain advances in saddle design, while marketed under the guise of 'increased security,' could be preventing individuals from developing an independent seat. The consequences of this were stressed by Coach L: *"If a rider cannot sit balanced, they need the rein and the leg for support, and who suffers? The horse."* Coach G furthered this by fervently asserting that: *"Two reasons why jockeys ride with really short stirrups - one is to get off the horse's back, and two is if they're going to fall off, they fall away from the horse. So it's the safest place to land,"* and contended that marketing a saddle with: *"bigger, thicker, fatter knee blocks,"* which they suggested fixes the rider into position to compensate for their lack of balance, is arguably putting riders at increased risk during a fall. Coach G also suggested that the endorsement of these products: *"using promotion with riders that people aspire to be,"* is a key influence on their purchase, and this reiterates individuals' desire to appear 'competent' [62] and the participants' concerns about individuals looking for the 'quick fix' to put them in a 'balanced' position rather than working on their horsemanship skills. While this is only an opinion, it points to a wider need for transparency and education in the use of equestrian products to support good practice.

Indeed, equestrians today, like everyone, are bombarded with a plethora of information competing for their attention, enhanced by algorithms, which are pandering to and reinforcing their desires. Participants noted that increased exposure to top-flight competition via streaming, enticing offers on the latest gadgets, and TikTok videos from self-proclaimed 'influencers' are shaping their expectations and ambitions for participation in equestrian sport. The integrity of online information, however, is unregulated, which is why equestrian sports organizations have embraced science in providing an evidence base for what constitutes good practice [6]. For some participants, this was a source of tension, primarily due to the perception that it often dismisses the validity of years of horsemanship experience sustained by horse practitioners, although it was also acknowledged that a great deal of scientific evidence has actually confirmed rather than challenged many long-held beliefs on horsemanship [63]. Coach N, however, cautioned against allowing experts in a very specific field to dominate the discourse: *"The horse will suffer eventually from so many people who have developed a minute part of what we all do into an 'ology,' and it's become their specialism; they can't do anything else."* Indeed, the welfare of the horse and strategies for best practice in equestrian sport require a much more holistic approach [59]. Despite some tensions, what these participants do have in common with scientists is their desire to learn more about the horse and continually improve applied practice in equestrian sport. Therefore, a platform that brings coaches and scientists together, and that is accessible for all, could provide a source of up-to-date educational information that is trustworthy and valid, endorsed by both equine welfare and coach education organizations. However, as Coach D stated, *"it's all down to storytelling,"* and what we have learned from the advances in social media is that information needs to be communicated with simplicity and clarity, in bite-sized chunks, brought

to life through lived experiences that audiences can connect with on a personal level [64,65].

Participants also acknowledged the varying eras of horsemanship and the evolution of good practice with horses, likening it to the societal changes in perception of how one raises a child. In both contexts, what constitutes good practice has and will continue to change over time with new knowledge. There are mitigating factors, however, which will influence whether and how that knowledge is used, at both an organizational and individual level, not least the unfiltered access to said knowledge [66]. Beyond this, the reliance is on the willingness of organizations to lead by example and, as Coach L asserted, where necessary, empower people to take action against poor practice: *"All organizations in this country, everyone should be held to account, so if they see abuse happening, the organization must act."* However, Coach L cautioned that this is not consistently the case, and that despite several recent high-profile investigations, there is too much power and influence held by elite riders: *"... but they do not, not always anyway... no matter who it is, you must act."* Equally, other participants were also quick to highlight that the social license to operate is not just an elite-level problem, and that incidents of poor practice need to be dealt with consistently across all levels of participation. The consequences, in terms of sustainability, if progress is not made on the ethical challenges to horses' participation in sport and the social perceptions thereof, will impact all equestrians and horse-related activities [42]. As Coach L went on to discuss: *"In this country government fund sport from top down, not bottom up,"* therefore funding in UK sport is currently determined by international success and medals won: *"If Equestrian isn't in the Olympic Games, FEI gets no funding, and therefore our government in the UK will say, well, you don't win medals so we'll cut your funding and it will have a serious knock-on effect, I think, for equestrianism in this country,"* likewise Coach M concurred: *"Without the horse having a value as a loosely speaking commodity, we don't have the investment to filter down to the whole population of horses."* In contrast, participants identified that Sweden operates a bottom-up funding structure, investing significantly in grassroots and less so in elite-level performance, and yet has still enjoyed considerable success internationally. Indeed, several participants observed the varying ways we could learn from policies and practices in different countries, for example, the licensing of horse ownership, the eligibility of humans and horses for competitive progression, and the regulation of coaching practice, some of which have already been operationalized in European countries [67].

Similarly, participants recognized that to increase sustainability, access to equestrian sport needs to be more inclusive, noting that cost is a key factor and looking to France as an example of some innovative ideas:

"I love the French Pony Club, where most of them have a nucleus of ponies which they then lease out to an individual rider for the period of the year ahead. But the Pony Club keeps a nucleus of ponies, it makes it much more cost-effective for the person to ride... We need to get thousands, tens of thousands more people riding. To do that, we have to make it more accessible, which means it has to be cheaper. So we have to find ways of doing our stable management cheaper,

and we have to find ways of giving people access to horses, which is cheaper." (Coach P)

Indeed, participants discussed the merits of social housing for horses, and while all participants recognized the socio-psychological benefits to horses of companionship in their living space, Coach H also highlighted the challenges of introducing a significant change such as this into a livery yard where: *"For the person that's been brought up and understanding that is the right thing to do, to be keeping horses in single stalls and not in small groups... I think you probably, as an individual, have to be quite brave to bring about change in that respect."* This is where coaches and practitioners need support from governing bodies and the scientific community to help them inform and improve receptivity to change and implement these changes effectively [68].

Participants also advocated that it should not go unrecognized that coaches experience significant personal conflicts and pressures themselves, particularly the burden of responsibility and the integral role they play for their human and equine athletes, and as such, should be provided with support to maintain good mental health [69]. Similarly, while participants conveyed a strong desire to protect our industry (Coach D) and maintain their own integrity as a coach by calling out poor horsemanship, Coach H discerned that one runs the risk of losing business: *"You do end up unfortunately losing, losing work and losing clients because they don't always want to hear that and then they get defensive,"* highlighting an intense personal vulnerability for coaches in enacting their moral and ethical responsibilities on behalf of the horse. It appears that the need for greater consideration of psychological safety extends beyond the human and equine athletes to coaches, too [70].

At an organizational level, participants observed several areas that are impacting sustainability. For example, as Coach K argued, the current infrastructure of governing bodies is not very economical: *"Four or five little fiefdoms going on and there's money coming down from government, actually all that's happening right now is we're wasting huge well, not huge sums, but for our sport, large sums of money with doubling up of lots of different roles,"* indicating that wasteful duplication of administrative positions means that funds are not: *"Having a good enough impact on the end user for athletes or for horse welfare."* Coach R also suggested that a more cohesive structure would support the ethical challenges faced by equestrian sport:

"The British Equestrian Federation needs to have a stronger say in all equestrian sports... each sport wants to be individual and I understand why they want to do that, but if we want some sort of cohesion to fight the hordes who don't want us to do whatever we want to do, then there needs some cohesion, some cohesive body at the top to sort of make that happen."

Likewise, concerns were raised regarding the inconsistency of messages from organizations regarding horse welfare [10]. Some participants advocated that greater effort is needed to counteract the dominant narrative of poor practice across social media with positive stories and examples of good practice. However, it is becoming increasingly evident that poor practice is far more prevalent than the organizations would care to admit [11], and more resolute and demonstrable action is needed. Coach K argued that the

response by equestrian organizations is: *"very defensive and lacking any real drive,"* and that the industry needs to demonstrate good practice through: *"the best knowledge and understanding that we have now and continue to evolve, we need to be confident because otherwise it's not the right people saying what we should be doing because the dialogue and the narrative is coming from somewhere else."* Indeed, the learned demonstration of best practice combined with a zero-tolerance approach to practices that challenge both human and horse welfare is needed for equestrian sport to remain sustainable [6].

What is considered to be best practice for training horses led to some interesting discussions. Coach P suggested that: *"the fundamental reason is that the horse is such an amazing creature that it will respond to so many different cues, and so we say that it works, therefore it must be the right way,"* recognizing that worldwide there are so many different approaches to horsemanship. In contrast, Coach B commented that, due to much more international exchange, there now appears to be greater homogeneity in equestrian training, referring more specifically to the Olympic equestrian disciplines:

"Everyone is starting to do things very, very similar. When I first started out in the horse world, you could go to an international show and you could separate an American rider from an English rider from a Spanish rider, from an Italian rider to a German rider, without even having to look at the national flags. Now it's much, much more even in that sort of way."

However, Coach B continued to explain that there is still 'No real blueprint' for the coaching of horse and rider, and worldwide, there are still significant variations in opinion on what is considered good practice. There are, of course, historical and sociocultural reasons for the existence of differing approaches, and indeed each facet of equestrianism has its own nuanced cultural values and intentions for the horse [71]. However, as Coach F stated, *"I see people who have always done it XYZ and they don't see a validity in doing it differently... there are people who are very much this is how we've done it, this is how we get success,"* which highlights the chilling reality that individuals' strong convictions about their practice are deeply motivated by the achievement of their personal goals within their chosen field and not the prioritization of the welfare of the horse [9–11]. The concerning factor here, in this naïve and self-serving perspective, astutely observed by Coach F, is that these individuals lose sight of the big picture: *"If we don't have some cohesion in thought process, then we can very easily be attacked by the people who are anti-horse sport. So, the cohesive and united we stand sort of attitude really, really needs nurturing and encouraging"* (Coach R). What is currently evident, however, is a reluctance to work together, regardless of equestrian discipline, to meet the challenges faced by the equestrian community as a collective whole and to unify the industry with regard to horse welfare and best practice [72]. Unfortunately, as Coach R noted, *"The human being is really not a very good person... it takes a real crisis before they unite in any way."* So here we are, in crisis, it is time to learn from our equine partners and recognize that we are stronger as a herd.

4. Limitations

The roundtable discussion generated some excellent dialogue, and the conversation was always enthusiastic,

free-flowing, and participants were always respectful of each other's point of view. As a trained psychologist, the lead researcher acting as facilitator had significant prior experience supporting individuals in sharing their perspectives and ensuring participants feel heard. However, it must be acknowledged that at the data collection level, within a roundtable setting, anonymity is not preserved, and confidentiality is reliant on the agreement and integrity of those present. Therefore, it could be argued that had this data been collected via one-to-one interviews, participants may have felt more comfortable speaking freely about their experiences or discussing more sensitive topics without concern for peer-judgement [73]. Likewise, what an individual advocates about applied practice versus how they practice can be entirely different [48]. While no such aspersions are cast upon the participants in this study, one way to extend this research would be to use a multifaceted approach of long-term observational studies on coaching practice, combined with one-to-one interviews with coaches and their athletes. Additionally, it must be acknowledged that the participants in this study are a small sample of a small population of coaches (i.e., BHS Fellows/UKCC Level 4), and the data provided were not representative of the entire equestrian coaching population in the UK, let alone worldwide. Therefore, this research could also be replicated with coaches of differing levels of qualification, as well as those who coach equestrian sports and activities across a broader range of contexts and cultures.

Furthermore, it would be remiss not to acknowledge that within a peer-group setting, there is a risk of participants offering socially desirable responses to the questions posed [74]. Given the current climate within equestrian sport of a 'social license to operate' and the fear of vilification for admission of any current or historical cases of poor judgment or wrongdoing with regard to horse welfare, it is understandable that individuals may have been cautious about what they shared in this forum. However, this again does speak to the lack of psychological safety within the current climate of equestrianism and serves as an opportunity to reflect on how we can address this and learn from past mistakes in a more compassionate way [70].

5. Conclusion

What was palpable across all the roundtable discussions was the knowledge and passion shared by this cohort of practitioners, which demonstrates that they are a vital source of support and counsel as key stakeholders and, in their role as coaches, are important influencers within the equestrian community. In fact, equestrian coaches, as a collective population, are in a unique position to generate positive global change for equestrianism through their individual, micro-level, daily interactions with humans and horses. At present, however, any action being undertaken by equestrian governing bodies to improve horse welfare is being driven from the outside in, from the external pressures of the wider public's opinion on equestrian sport. What is evident from this research is the opportunity to effect positive change from the inside out, through the way coach education informs coaches' values and behavior in their applied practice. Therefore, a priority must be that all routes to qualification in equestrian coach education ensure that, alongside the technical and coaching competencies, the ability to demonstrate and teach the skills and values which provide

psychological safety for humans involved in equestrianism is also trained and assessed.

Indeed, it is impossible to ignore that human behavior, be it at an individual or systemic level, is at the center of the majority of challenges we are facing in the industry; however, as has been advocated in the discussions, more effort needs to be made to understand the root causes of undesirable human behavior within equestrian sport. We need to create a psychologically safe space for honest and continued reflection on the ethics of our horsemanship practice, recognizing that in polarized ways this may bring discomfort for many individuals [70,75]. As Jones McVey [71] wisely observed, we all like to think we are ethical; however, our version of what is ethical is nuanced and differs from person to person and may be influenced by both culture and context. Therefore, while an individual should always be accountable for their own behavior, governing bodies must bring greater clarity and enforce the ethical parameters for participation in equestrian sport. Equally, as a community, we need to be willing to reflect on how equestrian cultures, organizational structures and policies, and the conditions of the performance environment may be reinforcing unethical behavior and poor practice, but we must do so in a compassionate way, recognizing that humans, as well as equines, are sentient beings.

Authors' Contributions

Conceptualization, Methodology, Data analysis, Writing—original draft preparation (LT). Data analysis, Draft submission review (NK), Data analysis (RW-S). All authors have read and agreed to the submitted version of this 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

The authors declare that there are no conflicts of interest.

Ethical Approval

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Exploration of Motivational Differences in German and Icelandic Equestrians

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Abstract

Little is known about how institutionalized structures in Germany and agrarian traditions in Iceland influence riders' motivational profiles and shape participation norms. In this study, we examine the extent to which differences in equestrianism depend on the cultural context and type of rider, thereby closing a gap in cross-national research on sport motives. A representative sample of German ($n = 788$) and Icelandic ($n = 145$) riders completed the Bernese Motive and Goal Inventory (BMZI). Group differences were analyzed using effect sizes, and a two-way ANOVA was conducted to examine interactions between country and rider type. Results revealed that competitive riders in both countries prioritized competition and external image, while leisure riders emphasized intrinsic motives such as nature engagement and well-being (e.g., Icelandic leisure vs. competitive, $d = 0.44$). German riders, supported by institutionalized sport structures, reported higher activation and aesthetic motives (German leisure vs. Icelandic leisure, $d = 0.45$), whereas Icelandic riders, influenced by regulatory challenges, prioritized heritage and practical horsemanship, with leisure riders reporting stronger distraction motives ($d = 0.59$). Cross-country interactions emerged, including German competitive riders valuing horse handling more than their Icelandic counterparts ($d = 0.74$). Perceived femininity of equestrianism was significantly higher among German riders ($d = 2.47$), and fitness and physique motives were low across all groups. These findings underscore the importance of sociocultural frameworks and gender perceptions in shaping equestrian motivations, advancing debates on how sports adapt to local identities, and informing more inclusive participation models.

Keywords

Sport motivation; sport motives; riders; equestrian sports; equestrianism; cross-cultural differences

1. Introduction

Athletes are typically driven by a mix of intrinsic and extrinsic factors, like performance, power, and affiliation as key motivators [1]. However, cultural contexts heavily influence which motives take priority. In Germany, health, fitness, and social interaction are stronger drivers of sports participation than competition [2]. Similarly, Nordic countries emphasize health and fitness motives more than Central Euro-

pean nations, reflecting cultural differences in how societies view sports [3].

The key characteristic of equestrianism is the interaction between humans and horses. Hence, success at competitions depends not only on the performance of the human, but also on the interaction between the pair. The sport's complexity also stems from the rider-horse partnership: success depends not just on the athlete's skill but also on the horse's well-being and responsiveness. As a result, competitive

riders balance external goals, like winning, with internal rewards such as overcoming fears or mastering challenges. In contrast, leisure riders - those who ride for recreation rather than competition - prioritize distinct motives related to the psychological benefits of riding, such as reduced anxiety, enhanced self-esteem, and improved problem-solving skills [4–6], which remain less explored in the research.

Given these distinctions, we investigate cross-national variations in motives among equestrian athletes and leisure riders, with a focus on Germany and Iceland. By comparing two unique equestrian traditions, our research illustrates the extent to which differences according to cultural context and gender perceptions play a role in participation goals, relationship dynamics with horses, and perceived rewards of equestrian involvement among athletes and non-athletes.

2. Literature Review

2.1. Equestrian Motives and Gender-Specific Perception of Sports

Overall, the motivation of equestrians is a little-researched topic [7,8]. Some studies have focused on elite equestrians, in which the motives of success and goal achievement were given priority [9,10]. In their study, Luke *et al.* [8] investigated equestrians' motivations for keeping and training horses. The main motive was achieving goals in equestrian sports. The respondents also stated that they worked hard to develop their knowledge and skills in equestrian sports. They were highly motivated to take part in competitions and club activities, and financial gain was important to many equestrians. In addition to the achievement of goals, it was therefore also about the need for autonomy and the need for connection in terms of the partnership between horse and human.

This emphasizes that gender plays a predominant role rather than being merely an option to consider in equestrian sports is gender. While men and women are physically active in different ways, traditional gender norms often dictate which sports are perceived as suitable. "Masculine" sports - linked to strength, risk, and competition (e.g., soccer, boxing) - attract more men, while "feminine" activities emphasizing aesthetics (e.g., ballet, skating) draw more women [11]. These choices reinforce traditional gender roles, with men prioritizing competition and physical prowess, and women emphasizing body image [12,13]. However, Kontro *et al.* [3] noted that men more frequently cite fitness and health as motivators, while women prioritize sociability, though exceptions exist. For example, Tóth *et al.* [14] found no significant gender differences in motives for sport persistence, suggesting complexity. Similarly, Seippel [15] highlighted overlapping influences: while social background shapes engagement, sport type, competitive level, age, and gender collectively influence participation patterns.

In equestrianism, motives and gendered norms interact in complex ways. Unlike most other athletic disciplines, equestrian activities depend on a dynamic human-animal relationship, combining athleticism with interspecies communication. Horses are not merely sporting equipment but responsive social partners, whose agency and emotional feedback shape rider experience [16]. This interspecies in-

teraction fosters distinct motivational profiles: affiliation motives (e.g., bonding with horses) often characterize leisure riding, while performance-oriented motives (e.g., technical mastery, competitive success) dominate competitive disciplines [17]. Competitive athletes across sports often prioritize skill mastery, achievement, and external validation, exhibiting ego-oriented behaviors such as showcasing superiority or seeking recognition [18,19]. For example, competitive cyclists and swimmers score higher on ego-oriented scales than their leisure counterparts, correlating with stricter training adherence [18]. In contrast, leisure participants typically emphasize intrinsic enjoyment, health, and flexibility, as seen in Norwegian leisure athletes, who prioritize fun and avoid rigid schedules [15,19]. Recent research has emphasized that such motives are mediated by the emotional attunement between rider and horse, where empathy, trust, and mutual responsiveness play a critical role [20]. This mirrors broader divides in sport participation between leisure and competition, while also introducing a relational, cross-species dimension rarely addressed in mainstream sport psychology [15]. Moreover, the psychological and developmental aspects of equestrian motives are deeply intertwined with gender-specific socialization processes [21–23].

From a developmental psychology perspective, equestrianism has long been conceptualized as a structured yet emotionally rich domain that supports girls' psychosocial growth. Early contributions proposed that horses function as transitional objects that facilitate developmental tasks. Meyer [24] and Rose [22] argued that interactions with horses support the transition from childhood to adolescence by fostering autonomy, affect regulation, and a sense of competence. Drawing on Bowlby's [25,26] attachment theory, Adolph and Euler [21] conceptualized the horse as a non-human attachment figure—a secure base that enables exploration while providing emotional safety and continuity. Their findings indicated that girls often experience equestrian engagement as emotionally stabilizing, empowering, and meaningful. In contrast, boys more frequently framed horses in instrumental terms, aligned with traditional masculine domains such as warfare, utility, and competitive success [27]. These gendered motivational patterns were substantiated in empirical studies. Euler [27], in a survey of 930 children and adolescents, found that girls disproportionately selected horses as their most desired possession, whereas boys prioritized vehicles; notably, boys' interest in horses declined with age. Gille *et al.* [28] interpreted this divergence as a product of gendered cultural codes that increasingly position equestrianism as a feminized space, leading to boys' gradual disengagement.

Recent findings corroborate the enduring emotional significance of equestrianism for girls. Hauge *et al.* [29] found that adolescent girls reported higher levels of emotional closeness, trust, and perceived companionship with horses than boys. These bonds were positively associated with psychological well-being indicators, including self-esteem and emotional resilience. The authors argued that for girls, the horse-human relationship continues to serve as a relational context for identity development and affective regulation. These findings reinforce earlier theoretical and empirical models, suggesting that equestrianism remains embedded in gendered developmental trajectories, where

relational and affective motives are particularly salient for female adolescents.

Historical analyses provide further insights into these gender-specific patterns. Hedenborg [30] examined their evolution in Sweden, Great Britain, and the USA, focusing on horse racing and the Olympic Games. While equestrianism was traditionally male-dominated, especially in military contexts, women in Sweden gained recognition as amateur riders and professional trainers. However, professional female jockeys faced restrictions until the 1970s. In contrast, Great Britain and the USA maintained stricter gender divisions, though Olympic equestrian events saw earlier female participation [31]. These trends illustrate equestrian sports' shift from male dominance to one of the few Olympic disciplines with mixed-gender competition, yet gender norms continue to shape participation and public perception.

The psychological benefits of equestrianism also contribute to its motivational appeal, particularly among women. Lee Davis *et al.* [16] conducted in-depth interviews with 52 women and 8 men aged 20 to 70, revealing that equestrian interactions were widely perceived as stress-relieving and psychologically beneficial, with female participants especially emphasizing the therapeutic aspects of horse–rider relationships. Similarly, Schütz and Warnstädt [32] surveyed 903 riders and non-riders, finding that non-riders associated equestrianism more strongly with femininity, whereas active riders – especially female riders – perceived it as a gender-neutral or even masculine sport. Additionally, female riders reported a stronger emotional connection to their horses, often describing them as trusted confidants who could sense their emotions and provide emotional support [32]. German male riders reported fewer psychological benefits compared to females, likely influenced by the sport's perceived femininity [33]. In Iceland, equestrianism is less gendered, with 47% of male riders reporting positive effects [34].

Beyond competitive aspirations, intrinsic enjoyment and well-being serve as primary motivators for equestrian participation. Gille *et al.* [28] examined non-competitive riders and found that over 90% identified their primary motive as the joy of interacting with horses. Other frequently mentioned motives included the physical and emotional benefits of riding, as well as the sense of freedom and escape that equestrianism provides. These findings align with Staats *et al.* [23], who found that women more frequently turned to animals, including horses, for social support, particularly in times of loneliness, whereas men tended to cite more utilitarian reasons for engaging with animals.

2.2. Equestrianism in Iceland

The regulations governing Icelandic horses and their participation in international equestrian sports present unique challenges for both riders and their horses. Rooted in historical and biological considerations, these strict rules aim to protect the genetic purity and health of the breed while simultaneously imposing limitations on Icelandic equestrian athletes. Icelandic horses are subject to a strict re-entry ban once they leave the country, a regulation dating back to the Althing parliament's decree in the year 982. This rule, designed to prevent the introduction of foreign equine diseases, has led to the complete isolation of the breed for over

a millennium [35]. While this policy has successfully safeguarded Icelandic horses from infectious diseases, it also means that any horse participating in international competitions must permanently remain abroad. Consequently, Icelandic equestrians face a difficult decision when entering international events, as competing with their horse requires accepting an irreversible separation.

The ban on horse re-entry has direct consequences for Icelandic equestrian sports. The FEIF World Championships, held biennially, can never take place in Iceland due to these import restrictions, forcing Icelandic riders to travel abroad for international competition. Additionally, riders must adhere to stringent biosecurity measures, as even leather riding equipment from other countries is prohibited from entering Iceland. Any non-leather gear must undergo extensive disinfection before importation [36], adding another logistical hurdle for Icelandic equestrians preparing for competitions. Beyond logistical complications, the emotional and financial ramifications of these regulations are profound [37]. Riders who compete internationally must either sell their horses abroad, establish permanent stabling outside Iceland, or abandon international ambitions altogether. This predicament often affects career trajectories, as some riders opt to remain in Iceland to retain their horses, while others relocate to participate in international events. The financial burden of maintaining horses abroad, coupled with the difficulty of securing sponsorships and transportation, further complicates international competition for Icelandic riders.

With a national horse population of approximately 80,000 and a human population of 382,000, Iceland maintains an extraordinary ratio of nearly one horse for every five inhabitants [34]. While this reflects the deep cultural and economic significance of equestrian activities, the challenges posed by international competition remain a contentious issue. Icelandic riders navigate the trade-offs between national regulations and global competition as a unique characteristic of Icelandic equestrian sports.

Despite these challenges for competitive riders, the regulations have inadvertently contributed to the global popularity of Icelandic horses. Today, approximately 180,000 Icelandic horses exist worldwide, with 100,000 residing outside of Iceland. This expansion has led to a growing international community of Icelandic horse enthusiasts and increased interest in equestrian tourism in Iceland. The Landssamband Hestamannafélaga, Iceland's national equestrian federation, regulates competitions, breeding, and education, ensuring the continued development of Icelandic equestrianism despite international restrictions. With a total membership of 12,470, it ranks as Iceland's fourth-largest sports federation and organizes the nation's most prominent equestrian events.

2.3. Equestrianism in Germany

The German Equestrian Federation serves as the central governing body for equestrian sports in Germany, overseeing 17 regional federations and 7,198 riding and driving clubs. With 3,347 affiliated equestrian centers and 57,163 direct members, the German Equestrian Federation coordinates seven core disciplines: dressage, show jumping, eventing, driving, vault-

ing, endurance riding, and para-equestrian sports. Sub-organizations include the German Olympic Committee for Equestrianism, the German Riders' and Drivers' Association, and the German Judges' Association, ensuring structured governance across competitive and leisure activities [38].

Equestrianism ranks among Germany's most popular sports, with approximately 2.32 million participants, including 840,000 active riders and 1.48 million occasional riders [39]. The term "rider" broadly encompasses individuals engaged in any horse-related activity, from competitive sports to leisure riding. Ownership and care arrangements reflect this engagement: 600,000 households own at least one horse, while 920,000 participate in leasing or shared ownership arrangements. Privately owned horses total 1.25 million, with 45% housed in boarding stables, nearly one-third kept privately, and the remainder kept on farms without formal riding facilities. Demographic trends reveal a decline in young riders but a growing cohort of participants over 40. Traditional disciplines dominate preferences, with dressage leading, followed by show jumping and gaited horseback riding. Notably, many unregistered riders prioritize outdoor riding over competitive pursuits, and most active riders began their engagement before age 12 [40].

The appeal of equestrianism in Germany extends beyond competition. A profound bond with horses and a desire to connect with nature are central motivators [40]. Emotional fulfillment often outweighs competitive ambitions, particularly among leisure riders. This aligns with a growing trend toward non-riding activities, such as groundwork, liberty training, and holistic horse care, which emphasize partnership over performance. A study conducted by the German Equestrian Federation [41] highlights the transformative impact of equestrian engagement: Riders scored higher than non-riders in traits such as determination, enthusiasm, and emotional balance, suggesting that long-term interaction with horses fosters personal development. Such findings reinforce the cultural perception of horses as catalysts for character-building and well-being [41].

The primary objective of this study is to compare motives for participating in equestrianism between Germany and Iceland, focusing on rider types (leisure vs. competitive), cultural contexts, and gender perceptions. Equestrianism adds complexity to this framework due to the unique rider-horse partnership. In Iceland, historical policies - such as the ban on re-entering exported Icelandic horses - reinforce cultural pride and exclusivity, creating motives tied to heritage preservation. These policies also impose logistical challenges for Icelandic riders in international competitions. Germany, conversely, emphasizes competitive excellence and leisure engagement, with female riders dominating participation (80% of German Equestrian Federation members are female; [40]).

This study explores whether German competitive riders are primarily driven by goal-oriented motives, such as competitive achievement, while Icelandic riders prioritize intrinsic or culturally rooted goals linked to their unique equestrian heritage. It also examines how perceptions of femininity in Germany may discourage male participation or influence their motives - potentially leading them to distance them-

selves from "feminine" associations - contrasting with Iceland's gender-neutral horse culture, which fosters shared motivations across genders. Furthermore, the analysis compares leisure riders in both countries, assessing their emphasis on flexibility, enjoyment, and horse-bonding versus competitive riders' focus on mastery and external validation. By incorporating gender-specific perceptions and cultural contexts, this study sheds light on the different motivations for participation in equestrian sports in Germany and Iceland and shows the extent to which there are differences in individual involvement in the sport, which may be associated with social norms, historical strategies, and gender-specific conditions, for example.

3. Materials and Methods

3.1. Procedure and Participants

We recruited 933 equestrians via social media (WhatsApp, Instagram, Facebook) between March and August 2024 through the online survey platform Unipark. Participants completed the questionnaire in German or English and provided active consent prior to participation. Descriptive statistics for the total sample and subgroups (Icelandic vs. German riders) are presented in **Table 1**.

3.2. Measures

Equestrian motives were assessed using an adapted and translated version of the *Berner Motiv- und Zielinventar im Freizeit- und Gesundheitssport* (BMZI; [42]), a German-language instrument designed to measure exercise-related motives and goals on a 5-point Likert scale (1 = *strongly disagree* to 5 = *strongly agree*). Subscale reliability using Cronbach's alpha was acceptable to excellent across both German and English versions (German $\alpha = .72-.91$; English $\alpha = .76-.95$).

Below, we provide brief descriptions, example items, and internal consistency for each motive, beginning with the BMZI subscales:

- Activation ($\alpha = .75$): stimulation, arousal, and energy enhancement. E.g., "*To feel energized and awake.*"
- Aesthetics ($\alpha = .84$): enjoyment of movement quality or environment. E.g., "*Because I enjoy experiencing the beauty of movement in sport.*"
- Competition ($\alpha = .86$): comparison with others and achieving superiority. E.g., "*To compete with others.*"
- Contact ($\alpha = .92$): social interaction and shared experiences. E.g., "*To be social with others.*"
- Distraction ($\alpha = .89$): psychological relief or detachment from daily stress. E.g., "*To reduce stress.*"
- Fitness ($\alpha = .86$): maintaining or improving physical condition. E.g., "*To maintain good physical condition.*"
- Physique ($\alpha = .91$): improving appearance or body shape. E.g., "*To lose weight.*"

Additionally, we included six equestrian-specific subscales developed by the authors to capture motives beyond those addressed by the BMZI. These were evaluated using explor-

atory factor analysis and demonstrated acceptable internal consistency (German $\alpha = .59-.78$; English $\alpha = .53-.89$).

- Enjoying horses ($\alpha = .59$): pleasure from being around horses. E.g., "Because I enjoy horses."
- Experience of nature ($\alpha = .77$): contact with nature through equestrian activity. E.g., "Because I like being outdoors in nature."
- External image ($\alpha = .75$): self-presentation and impression management. E.g., "Because it is a sport with a high reputation."
- Handling horses ($\alpha = .55$): enjoyment of horse care and grooming. E.g., "Because I like looking after horses."
- Well-being ($\alpha = .79$): mental and emotional health improvement. E.g., "Because horses make me feel good."
- Perceived femininity ($\alpha = .70$): alignment with gender norms and expressions. E.g., "For me, riding is more of a female sport."

3.3. Statistical Analysis

To assess group differences, we conducted a series of two-way analyses of variance (ANOVA) to examine the main and interaction effects. Post hoc comparisons were evaluated using effect sizes rather than significance testing, following Cumming's [43] recommendations, as we relied primarily on effect sizes in this exploratory approach to quantify the magnitude of differences. Differences are described through mean and standard deviation comparisons, with effect sizes reported as Cohen's d and interpreted according to Cohen's [44] guidelines: $d = 0.2$ (small), $d = 0.5$ (medium), and $d = 0.8$ (large). All analyses were conducted in R 4.4.1 (Posit, PBC, Boston, MA, USA).

4. Results

Table 2 reports means, standard deviations, and effect sizes (d) for all motivational dimensions, emphasizing between-country differences across competitive and leisure riders. These values form the basis of interpreting key group contrasts, particularly cross-national trends. In contrast, **Figure 1** visually highlights the motivational profiles for each rider group, differentiating BMZI-based and horse-specific motives. Together, **Table 2** and **Figure 1** support a detailed comparison of equestrian motives across national and role-based rider subgroups.

4.1. Activation

Activation motives revealed nuanced patterns. Within Germany, leisure riders reported slightly higher activation than competitive riders ($d = 0.18$, trivial). Icelandic riders displayed sharper contrasts, with leisure riders scoring notably higher than competitive riders ($d = 0.70$, moderate). Cross-nationally, German competitive riders reported substantially higher activation than Icelandic competitive riders ($d = 0.95$, large), and German leisure riders surpassed Icelandic leisure riders ($d = 0.45$, small-to-moderate). The largest difference emerged between German leisure and Icelandic competitive riders ($d = 1.37$, very large).

4.2. Aesthetics

Aesthetic appreciation varied significantly. In both countries, competitive riders prioritized aesthetics more than leisure riders (Germany: $d = -0.51$, moderate; Iceland: $d = -0.60$, moderate). Cross-nationally, German leisure riders valued aesthetics more than Icelandic leisure riders ($d = 0.33$, small), while Icelandic competitive riders showed marginally lower levels than German competitive riders ($d = 0.18$, trivial). The most pronounced difference occurred between Icelandic leisure and German competitive riders ($d = -0.88$, large).

Table 1: Demographic and group-specific characteristics of the sample.

Demographic variable	Total sample ($N = 933$)	Icelandic riders ($n = 145$)	German riders ($n = 788$)
Age, M (SD)	39.51 (19.31)	37.41 (17.99)	39.90 (19.53)
Female, n (%)	851 (91%)	33 (23%)	739 (94%)
Professional involvement, n (%)	284 (30.4%)	61 (42%)	232 (29%)
Horse owners, n (%)	615 (66%)	84 (58%)	531 (67%)
Horses owned, M (SD)	3.95 (9.86)	8.09 (17.22)	3.19 (7.56)
Riding discipline			
Gaited riding, n (%)	653 (70%)	87 (58%)	566 (72%)
Leisure riding, n (%)	115 (12%)	26 (18%)	89 (11%)
Breeding, n (%)	23 (3%)	13 (9%)	10 (1%)
Show jumping, n (%)	67 (7%)	-	67 (8%)
Classical horsemanship, n (%)	19 (2%)	11 (7%)	8 (1%)
Other, n (%)	60 (6%)	11 (7%)	49 (6%)

Dashes (-) indicate that this subgroup is not represented in the sample.

Table 2: Means and standard deviations for motives, and mean differences between Germany and Iceland by rider type.

Outcome	Leisure riders (n = 642)				Competitive riders (n = 291)							
	Germany (n = 536)		Iceland (n = 106)		Germany (n = 252)		Iceland (n = 39)					
	M	SD	e	d	M	SD	M	SD	e	d	M	SD
Activation	4.21	0.73	0.35	0.46	3.86	0.93	4.08	0.92	0.90	0.95	3.17	1.14
Aesthetics	3.47	1.14	0.36	0.31	3.11	1.31	4.04	0.93	0.19	0.20	3.85	1.17
Competition	1.88	0.88	0.01	0.01	1.87	0.74	3.40	0.85	0.19	0.22	3.22	0.89
Contact	2.96	1.01	0.26	0.25	2.70	1.04	3.07	1.00	0.33	0.33	2.74	1.07
Distraction	3.33	1.16	0.25	0.21	3.08	1.11	3.24	1.17	0.77	0.67	2.46	1.00
Fitness	2.89	0.98	0.11	0.11	2.78	1.01	2.98	1.02	0.20	0.19	2.78	1.17
Physique	1.57	0.82	0.06	0.07	1.51	0.78	1.61	0.89	-0.16	-0.18	1.77	0.96
Enjoying horses	4.68	0.48	0.06	0.12	4.62	0.63	4.70	0.63	0.30	0.48	4.40	0.62
Experience of nature	4.50	0.70	0.11	0.15	4.40	0.94	4.38	0.81	0.38	0.46	4.00	0.97
External image	1.56	0.78	-0.24	-0.28	1.80	1.06	2.28	1.07	-0.49	-0.45	2.77	1.04
Handling horses	4.44	0.64	0.04	0.07	4.40	0.74	4.49	0.71	0.53	0.74	3.96	0.79
Well-being	4.53	0.67	0.22	0.30	4.31	0.96	4.61	0.64	0.56	0.83	4.05	0.86

e: unstandardized mean difference; d: standardized mean difference. Large effects ($|d| \geq 0.8$, [44]) are marked in **bold**.

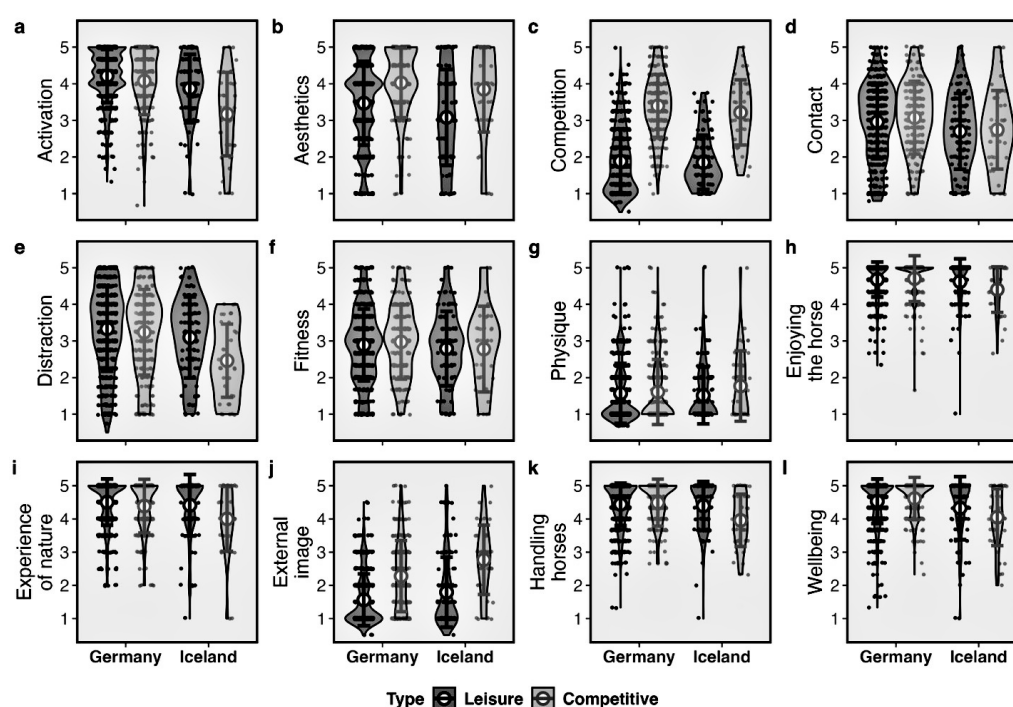


Figure 1: BMZI motives and equestrian-specific motives among competitive and leisure riders in Germany and Iceland. a–g: BMZI motives. h–l: equestrian-specific motives using items formulated for this study.

4.3. Competition

As expected, competition motives starkly divided leisure and competitive riders in both countries, with very large effects (Germany: $d = -1.74$; Iceland: $d = -1.74$). Cross-country differences were minimal for leisure riders ($d = 0.04$, trivial) and small for competitive riders (German > Icelandic: $d = 0.21$). Icelandic leisure riders reported far lower competition motives than German competitive riders ($d = -1.87$, very large).

4.4. Contact

Contact motives showed limited variation. Within-country differences were negligible (Germany: $d = -0.12$; Iceland: $d = -0.04$). Cross-nationally, German riders scored slightly higher than Icelandic counterparts (leisure: $d = 0.25$, small; competitive: $d = 0.33$, small). The largest gap was small-to-moderate ($d = -0.37$).

4.5. Distraction

Marked divergence appeared in Iceland, where leisure riders scored higher than competitive riders ($d = 0.59$, moderate). German differences were trivial ($d = 0.08$). Cross-country, German riders scored moderately higher than Icelandic competitive riders (leisure: $d = 0.76$; competitive: $d = 0.67$).

4.6. Fitness

Fitness motives showed minimal variation, with all differences trivial (within-country: $|d| \leq 0.08$; cross-country: $|d| \leq 0.19$).

4.7. Physique

Physique-related motives were consistently low. Icelandic competitive riders scored slightly higher than leisure riders ($d = -0.31$, small). Cross-country differences were trivial to small (max $|d| = 0.24$).

4.8. Enjoying Horses

Enjoyment was universally high. Icelandic leisure riders scored higher than competitive riders ($d = 0.35$, small), while German riders showed near-identical scores ($d = -0.05$). Cross-nationally, German competitive riders exceeded Icelandic competitive riders ($d = 0.48$, moderate), with a moderate gap between German leisure and Icelandic competitive riders ($d = 0.56$).

4.9. Experience of Nature

Nature-related motives were robust. Icelandic leisure riders scored higher than competitive riders ($d = 0.44$, moderate), while German differences were trivial ($d = 0.16$). The largest cross-country difference was moderate (German leisure > Icelandic competitive: $d = 0.70$).

4.10. External Image

Competitive riders reported higher external image concerns in both countries (Germany: $d = -0.81$, large; Iceland: $d = -0.92$, large). Cross-nationally, Icelandic competitive riders scored higher than German competitive riders ($d = -0.46$, small).

4.11. Handling Horses

Icelandic leisure riders scored higher than competitive riders ($d = 0.58$, moderate), while German differences were trivial ($d = -0.07$). German competitive riders exceeded Icelandic competitive riders cross-nationally ($d = 0.74$, moderate).

4.12. Well-being

Well-being motives were consistently high. Icelandic leisure riders scored higher than competitive riders ($d = 0.29$, small), while German differences were trivial ($d = -0.12$). German competitive riders reported higher well-being than Icelandic competitive riders ($d = 0.83$, large).

In summary, main effects of country were observed for the motivational factors activation, aesthetics, contact, distraction, handling horses, enjoying horses, and experience of nature. German and Icelandic riders differed significantly on these factors, with the largest country differences found for activation, followed by aesthetics and distraction. Significant main effects of rider type (leisure vs. competitive) were observed, particularly for competition, aesthetics, and experience of nature. Competitive riders scored higher on competition than leisure riders. Interaction effects between country and rider type were found for activation, distraction,

handling horses, and enjoying horses. The interaction effect was strongest for handling horses. Minimal variation across groups (country and rider type) was observed for fitness and physique. Across the entire sample, the motives physique and external image were rated comparatively low.

4.13. Differences in Perceived Femininity

To further illustrate differences across countries and riding contexts, we considered differences in the perception of equestrianism as feminine. The analysis revealed that in Germany, equestrianism is generally perceived as highly feminine, as indicated by the high mean score on the femininity perception scale (Figure 2). The difference between leisure and competitive riders within Germany is minor ($d = -0.12$), with competitive riders exhibiting slightly higher femininity perceptions. In contrast, in Iceland, the difference between leisure and competitive riders is more pronounced, with a strong effect size observed (Table 3).

Between-country comparisons show very large differences. Competitive riders in Germany perceive equestrianism as substantially more feminine than their Icelandic counterparts ($d = 1.51$), reflecting an entire scale-point difference on a five-point scale, a considerable gap given the sample size. The contrast is even more pronounced among leisure riders, with German leisure riders scoring higher in femininity perception than Icelandic leisure riders ($d = 2.10$). Cross-group comparisons reveal further notable effects: German leisure riders perceive equestrianism as substantially more feminine than Icelandic competitive riders ($d = 1.30$). The most substantial difference is observed between Icelandic leisure riders and German competitive riders, with a mean difference of 1.51 scale points and an absolute effect size of $d = 2.47$, indicating a particularly pronounced difference in perceptions.

These findings underscore the relevance of gendered perceptions in sport engagement. The pronounced main effects of perceived femininity in relation to rider type and country highlight the sociocultural framing of equestrianism as a gendered activity (Figure 2b). This framing appears to restrict participation, particularly among German males, as reflected in the demographic skew of our sample. The salience of these gender-related effects indicates that equestrianism may exert a stronger influence on motivational structures than cultural context alone.

5. Discussion

This study explored how motivational orientations vary between leisure and competitive equestrians in Germany and Iceland, revealing that participation is profoundly shaped by cultural frameworks and individual rider objectives. Intrinsic motivators, such as well-being and a connection with nature, are especially prominent among leisure riders, while those who compete tend to focus on extrinsic goals, including achievement and recognition. This division is consistent with Self-Determination Theory [45] and has been observed in a variety of sports, from cycling to team athletics, as documented by Moreno-Murcia *et al.* [18] and Seippel [15]. German riders, in particular, are inclined toward performance-oriented motives like activation and competition, whereas Icelandic riders place greater value on cultural connection and practical horsemanship. These patterns align

with the findings of Kontro *et al.* [3], which indicate that Nordic athletes often prioritize heritage and well-being over competitive outcomes, distinguishing them from their Central European counterparts.

A striking gender gap characterizes German equestrianism, where 94% of participants are female, reflecting broader sociocultural narratives that construct the sport as feminine. Such perceptions discourage male involvement, a phenomenon paralleling trends in other aesthetic sports [11]. In contrast, Iceland's equestrian culture is more gender-neutral, supporting balanced participation across genders. This contrast underscores the significant role of gendered socialization, rather than biological differences, in shaping motivations for sports participation [12,17]. The findings of Hauge *et al.* [29] reinforce this interpretation, as their intervention study found that adolescent girls derive pronounced emotional and psychological benefits from equine-assisted activities, including increased self-esteem, self-efficacy, and perceived social support. These effects were less pronounced among boys, suggesting that equestrianism may serve as a particularly salient context for identity formation and emotional development among girls.

The unique human-horse partnership emerges as a central component of equestrian motivation, especially in Iceland, where "handling horses" is highly valued among competitive riders. This dynamic extends achievement goal theory by illustrating how interspecies bonds can generate hybrid intrinsic and extrinsic rewards. Riders not only pursue personal accomplishment but also derive unique satisfaction from achieving goals in partnership with a trusted animal, a phenomenon documented by Hauge *et al.* [29] and further theorized by Dashper [17]. The horse, in this context, functions as both a secure base and an active collaborator, amplifying affiliation motives and providing emotional stability. This finding addresses a notable gap in the sports motivation literature, which has traditionally neglected the role of human-animal partnerships in shaping motivational orientations and psychological outcomes.

From a practical perspective, these findings suggest several actionable implications. Governing bodies and coaches in Germany should address the underrepresentation of men by rebranding equestrianism as a gender-neutral activity, for

example, by emphasizing its athletic rigor and historical associations with cavalry. Additionally, developing programs that integrate competitive goals with well-being could help retain a more diverse range of riders. In Iceland, leveraging cultural pride may enhance international competitiveness, and simplifying logistical challenges for athletes, such as subsidized overseas stabling, could help mitigate the effects of export restrictions.

In terms of participation and funding, promoting the psychological benefits of leisure riding, such as stress reduction and emotional resilience, may attract adult beginners and help counteract the decline in youth engagement seen in Germany. Emphasizing equestrianism's unique combination of competitive excellence and mental health benefits could also justify redirecting public funding toward community initiatives, including therapeutic riding programs for veterans.

Competition design should also reflect these insights. German federations might consider balancing elite events with competitions that reward horsemanship and partnership rather than focusing solely on technical metrics. Meanwhile, Icelandic federations could advocate for policy reforms to reduce barriers to international competitive participation.

This study makes a significant contribution to the sports motivation literature by addressing a notable gap: the traditional neglect of human-animal partnerships. The rider-horse relationship amplifies affiliation motives, as seen in the higher importance placed on "handling horses" among Icelandic competitive riders, exceeding levels typically observed in sports centered solely on human interaction. This dynamic extends achievement goal theory by illustrating how interspecies bonds can generate hybrid intrinsic and extrinsic rewards, such as the unique satisfaction derived from winning with a trusted animal partner. The cross-cultural perspective further refines our understanding of gender's influence, showing that while German men may distance themselves from equestrianism due to its feminized image, Icelandic men associate riding with national identity. This demonstrates how cultural narratives can override more universal gender norms in shaping sports participation and motivation.

Table 3: Means and standard deviations for perceived femininity and pairwise differences between Germany and Iceland by rider type.

Perceived femininity	Group 1				Group 2	
Group 1 - Group 2	M	SD	e	d	M	SD
Within-Countries						
Leisure (DE) - Competitive (DE)	3.06	0.71	-0.08	-0.12	3.14	0.66
Leisure (IS) - Competitive (IS)	1.63	0.49	-0.50	-0.90	2.13	0.72
Between-Countries						
Competitive (DE) - Competitive (IS)	3.14	0.66	1.01	1.51	2.13	0.72
Leisure (DE) - Leisure (IS)	3.06	0.71	1.43	2.10	1.63	0.49
Leisure (DE) - Competitive (IS)	3.06	0.71	0.93	1.30	2.13	0.72
Leisure (IS) - Competitive (DE)	1.63	0.49	-1.51	-2.47	3.14	0.66

DE = Germany; IS = Iceland; e: unstandardized mean difference; d: standardized mean difference. Large effects ($|d| \geq 0.8$, [44]) are marked in **bold**.

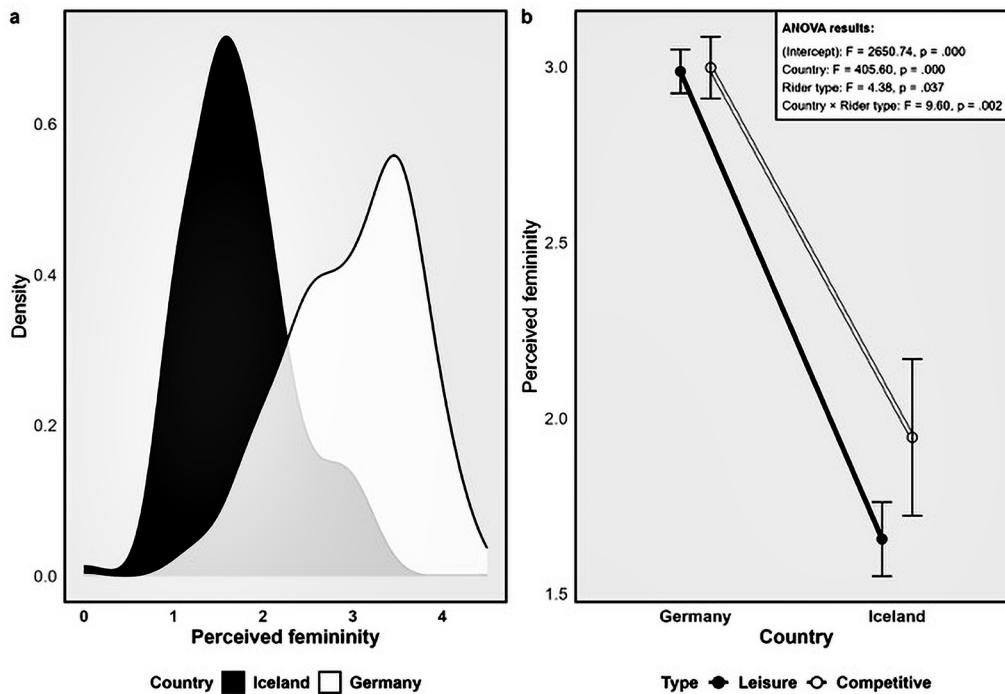


Figure 2: Differences in perceived femininity. a) Overall density of perceived femininity of equestrianism (1 = strongly disagree, 5 = strongly agree) between Germany and Iceland. b) Interaction of rider type and perceived femininity.

6. Limitations and Outlook

Several limitations of this study warrant careful consideration. First, the cross-sectional design restricts conclusions about causal relationships between cultural background, gender, rider type, and motivational orientations. Additionally, the relatively small sample sizes in specific subgroups, most notably competitive riders in Iceland, may reduce statistical power and limit the generalizability of subgroup-specific findings. While perceived femininity emerged as a central theme, it was modeled as an outcome rather than an explanatory factor; future research should examine its interaction with gender identity, rider type, and motivational profiles to better understand its potential mediating role.

Second, the study relied exclusively on self-reported motives and employed custom-formulated, equestrian-specific items. While these items captured domain-relevant content, the lack of complementary qualitative data limits interpretive depth. Incorporating interviews or open-ended questions in future studies could enrich the understanding of how equestrian identities are constructed and experienced across cultural and gendered dimensions.

Lastly, some concerns about measurement consistency must be noted. Differences in the internal reliability of the adapted BMZI scales and the equestrian-specific items may affect construct validity and comparability. This highlights a broader need for psychometric refinement and validation of domain-specific motivational instruments in equestrian sport research.

7. Conclusion

This study highlights differences in equestrianism motives between Germany and Iceland. While several core motives,

such as health- and appearance-related dimensions, showed minimal variation between groups, clear contrasts emerged in competition, aesthetics, and distraction motives, particularly among competitive riders. However, these motivational patterns alone do not fully explain the observed group differences. Instead, perceived femininity revealed the strongest divergence between countries and rider types, indicating that it plays a central role in shaping how equestrianism is experienced and framed. This finding is particularly significant given the different historical and cultural traditions in the use and meaning of horses in Germany and Iceland. The results underscore the influence of cultural and gender norms on motivational orientations within equestrianism. They also highlight the need to challenge restrictive gender expectations, especially within the German context, to foster more inclusive and equitable participation across genders.

Authors' Contributions

KS: Conceptualization, Methodology, Formal analysis, Validation, Writing – Original draft, Writing – review & editing. CS: Formal analysis, Software, Validation, Visualization, Writing – Original draft, Writing – review & editing. MH: Conceptualization, Data curation, Writing – Original draft, Resources.

Data Availability

The data and analysis code for this study are available upon reasonable request. Item wordings are accessible on the Open Science Framework: <https://doi.org/10.17605/OSF.IO/YFMC6>.

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Conflicts of Interest

The authors declare that they have no conflicts of interest.

Ethical Approval

This study was conducted in compliance with all applicable laws and institutional guidelines, adhering to the ethical standards of the university. Informed consent was obtained from all participants prior to their inclusion in the study. The rights, privacy, and confidentiality of all participants were strictly maintained throughout the research process.

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Effect of a Single Acupressure Treatment on the Mechanical Nociceptive Thresholds (MNTs) of the Equine Epaxial Back Musculature

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Abstract

Aims: Equine acupressure therapies possess an abundance of acclaimed anecdotal evidence; however, scientific validation remains limited. This investigation aimed to explore the effect of manual acupressure on the mechanical nociceptive thresholds (MNTs) of the equine epaxial musculature. **Materials and Methods:** The study design was a randomized, single crossover trial involving ten horses (five geldings and five mares) of various ages (16 ± 4.49 years). Horses were split into two groups and received a 10-minute acupressure or sham treatment. Nine acupressure points were selected and treated with 30 seconds of direct light pressure followed by six full circles. Each horse was assessed for points of sensitivity at three points bilaterally along the epaxial musculature, before, immediately after, and one day after the acupressure or sham treatment. A two-week washout period was implemented; the groups were reversed, and the protocol was repeated. Data were both parametric and nonparametric; therefore, to ascertain whether differences occurred in MNT values across the time points, a series of repeated measures ANOVAs and Friedman's analyses were undertaken. Where significant differences were found, post hoc Wilcoxon tests with Bonferroni correction identified how MNTs differed with time. Further paired t-tests or Wilcoxon rank tests determined whether differences occurred in the percentage of change between the treatment and control groups. **Results:** The results of the study suggest that acupressure elicits an immediate increase in MNTs in the epaxial musculature, most significantly at the thoracolumbar region. A decrease in this response could indicate lower sensitivity of the back, allowing better back kinematics and possibly improved performance.

Keywords

Horse; pressure algometer; complementary therapies; muscle tension

1. Introduction

As the equine industry expands [1], so too does the requirement and appeal for a wider range of therapies to complement veterinary medicine. While complementary therapies remain controversial due to limited supporting evidence [2], their popularity persists [3]. Acupoint therapies, an integral part of traditional Chinese medicine (TCM) for over 3,000 years, are now used worldwide alongside everyday medical practices [4]. According to TCM, the stimulation of

acupoints along meridian systems aids in balancing energy flow and enables the body to heal itself naturally [5]. In contrast, Western medicine views acupoints as cutaneous areas of increased electrical conductivity that, when stimulated, provide therapeutic effects [6]. Animal acupuncture has been documented since the 17th century, but its modern use is largely owner-driven, reflecting the popularity of acupoint therapies in human medicine [7–9]. In humans, acupressure therapy has been shown to improve symptoms

such as nausea [10,11], anxiety [12,13], insomnia [14], depression [15,16], fatigue [17], and pain [18–20]. Acupressure is noninvasive, easily accessible, low-cost, and may offer advantages over drug-based treatments by limiting potential side effects [21].

Although the formal structure of an acupoint is debated, research indicates that it is distinct from nonacupoint tissue [22]. According to TCM, an acupoint is an area of the body where the internal energy concentrates at the surface. With a light touch, they can be palpated as slight depressions, and by TCM practitioners, they were mapped out due to their ability to provide therapeutic effects [23]. They were later translated into "transpositional points" for animal anatomy [24,25]. Histological studies reveal increased density of nitric oxide, blood vessels, mast cells, lymphatics, and nerves at the site of an acupoint [26–29]. Mingfu *et al.* [27] also reported channel-like extensions of these structures, consistent with meridian theory. Correlations have been noted between acupoints and myofascial trigger points, with Melzack *et al.* [30] reporting a 71% correlation, although later analyses suggest that this may be closer to 18–19% [31]. Despite the fact that each point was independently discovered, it is possible that they refer to the same phenomenon – namely, that pressure applied to a specific body part results in pain relief [32]. While such associations remain unconfirmed in horses and may vary with anatomy, Langevin and Yadov [33] found a correlation of 80% between acupoints and the location of intermuscular and intramuscular connective tissue planes, suggesting a possible anatomical or fascial basis for traditional meridian theory [32,34].

In TCM, Qi is considered central to health by stimulating the upregulation of cells, blood flow, nutrient absorption, and homeostatic maintenance [22]. Acupoint therapies are, in theory, designed to promote the flow of Qi and enable the rebalance of the body's energy. In conventional medicine, Qi is thought to correspond with bioenergy as adenosine triphosphate (ATP) [35]. Mitochondria generate ATP via oxidative phosphorylation [36]. With regard to Qi, numerous diseases are related to mitochondrial dysfunction [37–39], and evidence suggests that mitochondria may play a role in maintaining homeostasis [40]. Therefore, a connection between ATP and Qi has been suggested [41,42]. Supporting this, acupuncture may regulate ATP release [43,44]. Mast cells are abundant in acupoints [45], and when stimulated, they degranulate and increase local histamine and adenosine concentrations, further promoting ATP synthesis and supporting this speculation [46,47].

Acupressure has been reported to increase local blood flow [48,49] and skin temperature [50], possibly through ischemic compression [51,52], or the release of vasodilators such as substance P and nitric oxide (NO). Although findings are mixed, some studies noted elevated NO after acupressure [53] and reduced substance P after acupuncture [54], while others remain inconclusive [55,56]. Acupressure may also act via pain-gate control, with A-beta fiber stimulation inhibiting nociceptive transmission [57–60]. Endogenous opioids have been proposed as another mechanism, but evidence remains inconsistent. No significant changes in β -endorphin levels were found in two trials [61,62], although both reported upward trends. Similarly, serotonin responses

vary: some studies observed increased levels after auricular acupressure [63], while others found no effect [64]. Differences in participant pathology and concurrent treatments may contribute to this inconsistency. As endogenous opioids typically act with some delay [65], and rapid responses to acupressure have also been documented [66,67], it is likely that multiple mechanisms are involved.

Despite widespread practical use and publications describing acupressure techniques in horses [68,69], scientific evidence in the species is limited. One case study reported improvement in stringhalt following acupressure [70], but the absence of a standardized protocol and concurrent therapies precluded firm conclusions. More robust evidence exists for other acupoint therapies, such as acupuncture, which has been studied for equine musculoskeletal problems [71–77]. While findings are encouraging, methodological variation and inconsistent outcomes limit their interpretation. Consequently, treatment parameters for equine acupressure remain unvalidated, and the scientific evidence is insufficient to justify its routine clinical use. Nonetheless, anecdotal support is abundant, highlighting the need for controlled studies to clarify its potential role.

We hypothesized that a single treatment of acupressure would have an effect on the mechanical nociceptive thresholds of the equine epaxial musculature compared with a sham treatment.

2. Materials and Methods

2.1. Animals

A sample population of ten adult horses (*E. caballus*) of various ages (16 ± 4.49 years old), genders (geldings, $n = 5$; mares, $n = 5$), breeds (Appaloosa, $n = 1$; Thoroughbred, $n = 1$, Welsh x Arab, $n = 1$; Dutch Warmblood, $n = 1$; Irish Sports Horse, $n = 2$; Belgian Draught x, $n = 1$; Irish Draught, $n = 1$; Cob, $n = 1$; Irish Cob, $n = 1$), weights (567.8 ± 75.45 kg), and heights (15.3 ± 1.03 hh) were used. All horses had similar management techniques and similar exercise regimes consisting of riding school activities before and during the trial period. Horses were not ridden or exercised between the treatment and the one-day post-treatment MNT assessment. During this period, they resumed their usual turnout and stabling routine. All horses used in the trial were assessed for lameness and were graded as $<1/5$ on the American Association of Equine Practitioners (AAEP) lameness scale. Horses were also free from any diagnosed pathology. During the treatment or sham, each horse was held by a handler but was otherwise allowed to stand freely and adopt a natural posture throughout the session. All horses maintained a consistent routine throughout the duration of the study. Apart from the days when testing took place, no changes were made to their workload, management, or environment. This was to minimize external variables that could influence the functional status of the horses or the outcome measures. The sample size was calculated using the resource equation approach [78] and the National Centre for the Replacement, Refinement, and Reduction of Animals in Research (NC3R) power calculation tool. Assuming the methods differ slightly in their interventions and outcomes, and considering the mean effect size of a similar study [79], to obtain statistical discrimination, it has been calculated that for a 90% power with a $\alpha = 0.05$, nine horses would be needed as a minimum sample [80].

2.2. Experimental Design

The experimental design used for this trial was a randomized, single crossover design, utilizing a convenient sampling method, which has previously been used in acupuncture research [75,81]. A random number generator was used to randomly allocate the horses (n = 10) into two groups: A or B. A single 10-minute acupressure treatment was given to the treatment group (A) and a sham treatment was given to the control group (B) by the same therapist. The MNTs were measured before the treatment/sham, immediately after the treatment/sham, and one day after the treatment/sham. Once the first treatment and measurements were complete, a washout period of two weeks was implemented to reduce any carryover effects. The groups were then swapped and the protocol repeated.

2.3. Acupressure Points

Nine acupressure points were selected for this study, as research has advised against treating more than 11 points per session [75]. Acupoints were chosen based on suggestions from the available literature on their use for equine and human back pain. Table 1 outlines the full list of points and associated literature. Point location was based on transpositional location and the aid of descriptions outlined in the literature suggestion [82,83]. The specified distance of 9 cm from anatomical landmarks was fixed and consistently applied across all horses, regardless of individual size or morphology, to ensure standardization of point placement. A visual depiction of point location is displayed in Figure 1. The stimulation of acupressure points was completed cranial to caudal, with points being stimulated on the left first, followed by the right side. The points and order of stimulation were consistent across all individual horses, as implemented in previous trials [75–77,84].

2.4. Acupressure and Sham Application Method

Each acupressure point was treated with 30 seconds of direct finger pressure. Pressure was initially applied lightly, defined as sufficient to produce visible skin indentation without causing blanching or deeper tissue deformation (approximately 3–4 mm). Over the first 20 seconds, pressure was gradually increased in accordance with tissue compliance, and the horse's behavioral acceptance was indicated by the absence of avoidance, such as muscle tension or movement. The final level of pressure remained within a range considered tolerable and non-aversive, ensuring consistent and ethical application across all horses. Continuing with the same level of pressure, six full circles were applied at the point, with the digit maintained in firm contact with the skin. The pressure during these circular movements was kept equivalent to the final sustained pressure from the initial 30-second application. Stimulation of acupoints by direct finger pressure has been described in veterinary acupressure publications [85,86]. The sham treatment followed the same treatment protocol, except instead of applying pressure, the therapist held their finger approximately one inch above the acupoint for the same time as the treatment without contacting the horse at any stage. The therapist delivering the acupressure was trained and assessed in the acupressure protocol by an experienced and qualified veterinary physiotherapist.

Table 1: Selected acupressure points and associated literature.

Acupoint	Location	Associated literature
Governing Vessel 20	At the highest point of the poll, rostral to the occipital crest.	[73,83]
Bai-Hui	On the dorsal midline at the lumbosacral space, in the depression between the spinous processes of the last lumbar and first sacral vertebrae.	[75,82,83,87]
Bladder 20	9 cm lateral to the dorsal midline at the 17 th intercostal space.	[83,88,89]
Bladder 13	9 cm lateral to the dorsal midline at the caudal edge of the scapula cartilage, at the eighth intercostal space.	[83,89]
Governing vessel 3	On the dorsal midline at the 3 rd lumbar vertebra.	[73,83]
Bladder 15	9 cm lateral to the dorsal midline in the 10 th intercostal space, in the iliocostal groove.	[83]

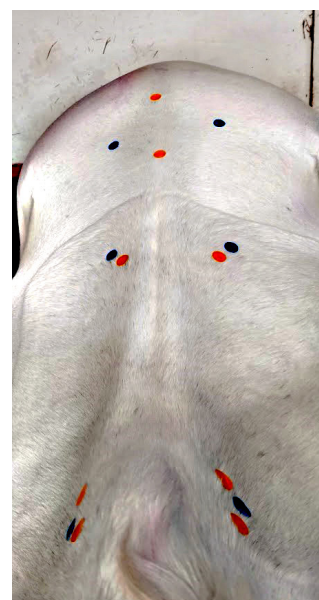


Figure 1: Acupressure (orange) and MNT (blue) point locations.

2.5. Pressure Algometry Points

Pressure algometry is an objective method of quantifying pressure sensitivity, and studies have confirmed its effectiveness in measuring MNTs in the musculoskeletal structures of horses [90–92]. Human studies have also utilized it to evaluate acupuncture [93] and acupressure [19,94], and research in horses has utilized pressure algometry to evaluate electro-acupuncture [73]. The three points chosen were largely adopted from Varcoe-Cocks *et al.* [95] and Haussler and Erb [90]. Table 2 outlines the exact anatomical location of each point, and Figure 1 displays a visual depiction of the points. Previous studies have found these MNT points to produce easily repeatable results [95]. Either side of T12 has been shown to produce high muscle activity amplitudes [96], as well as increased peak pressures within ridden horses [97]. Increased muscle activity and pressures in this area

may predispose the horse to back pain, which is why both MNT measurement and acupressure points were selected in this area. Point 2 was chosen, as this is an area where the back of the saddle commonly sits. Due to stabilization and vertebral differences in the lumbar vertebrae, lumbar pain is a critical factor in the loss of performance in horses [98,99]. Point 3 was therefore chosen to represent the response to acupressure here.

2.6. Pressure Algometry

A Force Ten™ FDX 100 pressure algometer (Wagner Instruments, USA) was used to measure MNTs, measuring in Newtons (N) to two decimal places, with a blunt 1 cm² rubber tip. MNTs were measured at six points along the back (three bilaterally; see **Figure 1**). The points were measured out and marked with stickers, as stated in **Table 2**. The algometer readings were covered to reduce possible bias from the researcher. The algometer was held perpendicular to the tissue and held in light contact initially to reduce startle reactions. Pressure was then gradually increased for three seconds until a reaction to the stimulus was perceived; after which, pressure was immediately withdrawn. A positive reaction indicative of reaching the MNT included muscle twitch, weight shifting, facial grimace, tail swish, or head movement, as previously described in literature [91]. An experienced handler was present during all measurements and also monitored the horses' reactions to confirm the primary investigator's observations. Each point was measured three times to ensure consistency. The measurements were obtained in a random order and taken at the same time of day for each horse, as this has been shown to influence perception [100,101]. MNT measurements were taken before, immediately after, and one day after the treatment or sham.

2.7. Statistical Analysis

Statistical analysis was performed using SPSS version 28.0 (IBM Corporation, Statistics for Windows, Portsmouth, UK). Descriptive statistics were calculated, including means and standard deviations, and the distribution of MNT data was assessed using the Shapiro–Wilk test. To establish whether the left and right data should be combined, comparisons between the left and right MNT values were assessed using either a paired t-test for normally distributed data or a Wilcoxon signed-rank test for data that violated normality assumptions. When all relevant data sets were normally distributed, a one-way repeated measures ANOVA test was used to compare absolute MNT values across the time points. If the data violated assumptions of normality, the nonparametric Friedman test was used instead. Where significant results were established, post hoc analyses were conducted following both tests to identify specific pairwise differences. Bonferroni post hoc analysis was carried out to determine differences between the conditions (pre-treatment, post-treatment, one day post-treatment), with significance set at $P \leq 0.05$ for all outcome parameters. Instead of applying the Bonferroni correction to the significance level (alpha), this study reported the Bonferroni SPSS-adjusted P values (P values based on Fisher's least significant difference multiplied by the number of comparisons). SPSS adjusts the

actual p -value by applying the Bonferroni correction backwards. This allows assessment of significance with reference to the traditional alpha of 5% without increasing type II errors. Similar statistical tests have been utilized in previous acupressure research [17,102,103]. The percentage change at each value from pre-treatment and post-treatment was calculated and compared between the groups, utilizing a paired samples t-test when all relevant data were parametric and a Wilcoxon signed-rank test when data were nonparametric. All statistical significance was set at $P < 0.05$.

3. Results

3.1. Baseline Measurements

There was no statistically significant difference between the combined MNTs of the treatment group pre-treatment (Median = 69.34 N) and the sham group pre-treatment (Median = 68.89 N) ($P = 0.88$), indicating comparable study populations.

3.2. Differences at Timepoints

There was a statistically significant difference between the data on the left (median = 71.22 N) and right (median = 73.91 N) sides ($P = 0.03$) at the MNT measurement points. Therefore, it was decided to separate the left and right data in the results. Data are presented as mean $\pm$ standard deviation unless otherwise stated.

At T18 on the left, MNT measurements were statistically significant at the different time points within the acupressure treatment group, $F(2,18) = 4.151$, $P = 0.03$. Post hoc analysis with a Bonferroni adjustment revealed that MNT scores were statistically significantly increased immediately post-treatment (70.94 ± 18.98 N) in comparison to pre-treatment (60.56 ± 18.82 N), with a mean difference of 10.38 N ($P = 0.01$) (**Figure 2**). Likewise, at T18 on the right, there was also a statistically significant difference at the different time points within the acupressure treatment group, $F(2,18) = 4.629$, $P = 0.02$. Post hoc analysis revealed that MNT scores were statistically significantly increased immediately post-treatment (76.06 ± 20.29 N) in comparison to pre-treatment (63.66 ± 18.72 N), with a mean difference of 12.39 N ($P = 0.01$) (**Figure 3**). At L6 on the left, MNT scores were statistically significantly different at the time points within the acupressure treatment group, $\chi^2(2) = 7.80$, $P = 0.02$. Post hoc analysis revealed a statistically significant difference between the acupressure treatment group one day post-treatment (86.84 ± 24.85 N) in comparison to pre-treatment (74.87 ± 27.45 N), with a median difference of 11.97 N ($P = 0.021$) (**Figure 4**). No significant difference was determined within the treatment groups at T9 or L6 on the right ($P > 0.05$). No significant difference was determined at any of the time points within the sham groups ($P > 0.05$).

Table 2: MNT measurement points and anatomical location.

Point	Location
1 T9	10 cm distal from the DSP of T9.
2 T18	10 cm distal from the DSP of T18.
3 L6	10 cm distal from the DSP of L6.

3.3. Percentage Change

At T18, there was a higher percentage of change in the treatment group (Median = 16.3%) in comparison to the sham group (Median = 6.19%), showing a statistically significant difference between the two groups ($z = -2.128$, $P = 0.03$) (Figure 5). At T9, there was a higher percentage of change in the treatment group ($15.00 \pm 23.64\%$) in comparison to the sham group ($8.92 \pm 20.77\%$); however, there was no statistically significant difference between the two ($t(19) = 0.76$, $P = 0.45$). At L6, there was also a higher percentage of change in the treatment group ($14.0 \pm 28.57\%$) in comparison to the sham group ($7.77 \pm 25.64\%$), although there was no statistically significant difference between the two groups ($t(19) = 0.85$, $P = 0.40$).

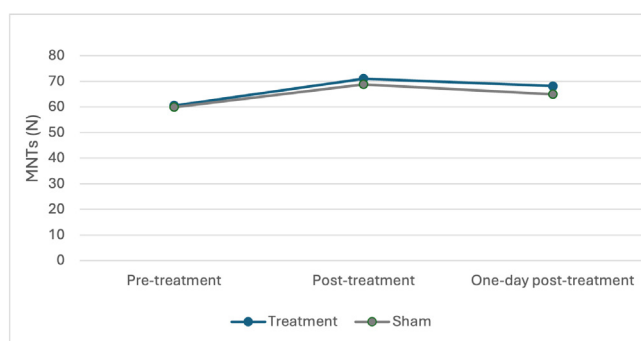


Figure 2: Mean MNTs at pre-treatment, post-treatment, and one-day post-treatment for the treatment and sham groups at point 2 (T18) on the left, illustrating the significant increase in MNTs in the treatment group pre- and post-treatment ($P = 0.01$).

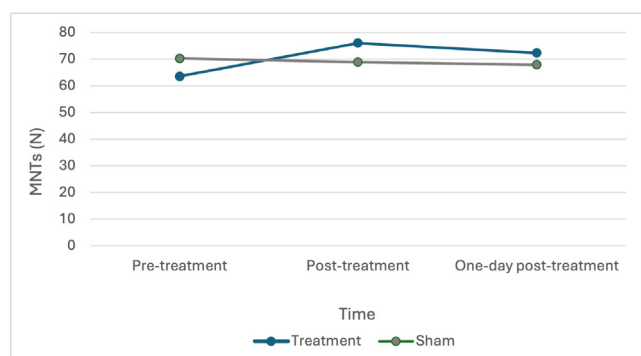


Figure 3: Mean MNTs at pre-treatment, post-treatment, and one-day post-treatment for the treatment and sham groups at point 2 (T18) on the right, illustrating the significant increase in MNTs in the treatment group pre- and post-treatment ($P = 0.02$).

4. Discussion

The purpose of this investigation was to determine whether a 10-minute manual acupressure treatment altered the mechanical nociceptive thresholds of the equine epaxial musculature compared to a sham treatment. The findings support the proposed hypothesis: a single treatment of manual acupressure was associated with a statistically significant increase in the MNTs at T18 bilaterally immediately following treatment and at L6 on the left one day after treatment. Furthermore, there was also a statistically significant increase in the percentage of change at T18, of 16.32%, following a single treatment of acupressure. Other untested regions of the

epaxial musculature may have undergone alteration and reacted to acupressure in a similar way. However, it would be challenging to obtain statistically significant results across all domains given the small sample size and the distinct nature of measurement [104]. Therefore, the statistically significant findings from this study, although limited, are still useful in comprehending the effects of acupressure. To the authors' knowledge, this is the only study within the equine sector measuring the effect of acupressure on muscle nociception; therefore, comparability of the results is limited. However, results coincide with previous research in humans [105–107] and following electro-acupuncture in horses [73]. Direct comparison with these studies is challenging due to the employment of auricular acupressure and electro-acupuncture, which could be considered different modalities, providing different therapeutic effects [108]. Regardless, there is preliminary evidence to suggest that acupressure may influence muscle nociception. Rungsri *et al.* [73] performed a 15-minute electro-acupuncture treatment resulting in significantly increased pressure thresholds. Within this study, they stimulated the Bladder and Governing Vessel meridians, with similar points treated in the present trial. Although further research is required for confirmation, these results combined suggest that acupoints located along these meridian channels may be beneficial for reducing back sensitivity in horses.

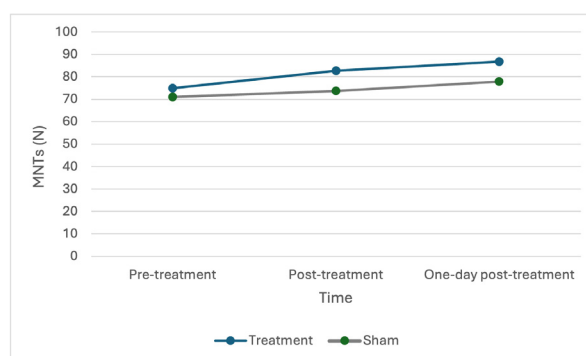


Figure 4: Mean MNTs at pre-treatment, post-treatment, and one-day post-treatment for the treatment and sham groups at point 3 (L6) on the left, illustrating a significant difference between the MNT scores in the treatment group at pre-treatment and one-day post-treatment ($P = 0.02$).

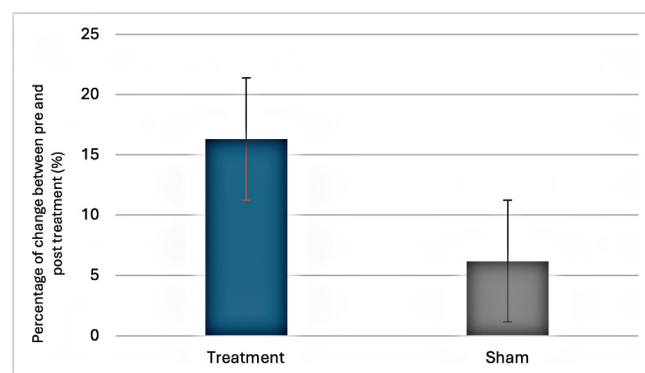


Figure 5: Median percentage of change in MNTs between pre-treatment and immediately post-treatment for the treatment and sham groups at point 2 (T18), illustrating a statistically significant difference between the two groups, ($P = 0.03$).

A significant increase in MNTs was observed at T18 immediately following acupressure, suggesting that the thoracolumbar region of the epaxial musculature may be particularly responsive to treatment. This site showed lower baseline thresholds than T9 and L6, indicating greater pre-existing sensitivity, which may explain why there was a greater effect. Similar findings have been reported in both human and equine studies, where acupuncture and acupressure were more effective in individuals with pain compared to asymptomatic subjects [65,94,109,110]. This supports the concept within traditional Chinese medicine that acupoint therapies restore balance most effectively when dysfunction is present [6]. In this study, although horses were excluded if they displayed lameness or had a diagnosed pathology, no formal functional or musculoskeletal assessment was conducted. Therefore, the presence of subclinical pain cannot be excluded. Furthermore, while management and workload were kept consistent, minor day-to-day variations in activity may have influenced the horses' physiological status and should be considered when interpreting these findings.

Left and right results were analyzed separately to account for potential asymmetry, but consistent lateralized effects were not observed across all points. While T18 showed bilateral significance immediately post-treatment, only the left L6 site was significant at one day post-treatment, likely reflecting individual variability, normal asymmetry in muscle response, or a type I error rather than a systematic side effect. Previous studies have also reported side-to-side differences in algometry readings [95], possibly related to habitual handling and mounting practices [111–113]. Although intended to standardize procedures, this may have introduced bias and contributed to side-specific differences.

A decrease in MNTs following manual acupressure may indicate reduced spinal sensitivity, potentially improving kinematics and movement. Back pain has been shown to alter spinal kinematics, with horses exhibiting compensatory extension and lateral bending of the thoracic spine [114–116]. Collectively, these studies underscore the close link between spinal sensitivity and kinematics in equine back health. The observed decrease in MNTs following acupressure may reflect a reduction in spinal stiffness, facilitating improved movement. Nonetheless, given the complex and multifaceted etiology of equine back pain, clarity regarding how changes in MNTs relate to functional outcomes and long-term performance is warranted.

The underlying mechanisms of analgesia elicited by acupressure remain uncertain. An induction time of 15–20 minutes is required for the development of analgesia through the endogenous opioid pathway [65]. Therefore, the immediate effect observed in this trial could be mediated through the neural afferent nociceptive pathway and pain-gate mechanism [117]. Repeated stimulation of acupoints through acupressure may reduce the threshold for nociceptor activity, causing central sensitization and decreased receptor sensitivity, thereby increasing MNTs [118]. It is possible that stimulation of the peripheral sensory neurons through acupressure also elicits the release of endogenous opioids. However, as no other time points of nociception were recorded within

this trial, whether a second peak increase in nociception occurred at 15–20 minutes cannot be confirmed.

Although no statistically significant changes were detected in the sham group, increases in MNTs were observed at several sites (Figures 2–5). This may reflect therapeutic elements of the sham procedure itself. Acupoint therapies are often emotionally focused, which could initiate relaxation and subsequent decreases in muscular nociception [119]. Previous improvements in sham acupressure treatments have been documented, giving strength to this speculation in both humans and animals [20]. While the mechanisms are unclear, possible contributors include classical conditioning, the therapeutic environment, and study population characteristics [120]. Moreover, although acupressure and MNT measurement points were selected independently, the pressure applied during algometry readings could stimulate sensory receptors and transiently alter sensitivity. Repeated exposure to algometry has been reported to induce habituation or sensitization in a proportion of horses [91,121], although a pattern is difficult to establish, and it may be influenced by examiner consistency, resulting in false positive habituation or sensitization [122]. The inclusion of an intervention further complicates the ability to differentiate the accuracy of algometer variations. These confounding effects should be considered, and future studies may benefit from incorporating additional control conditions.

4.1. Limitations

The major limitations of this study include the small sample size ($n = 10$), which predisposes the results to reduced trend visibility and outlier bias [114]. The sample may also not be representative of the equine population, as algometry results can be influenced by age, breed, sex, and body condition [90]. The carryover effects of acupressure have not been well examined; therefore, it could not be determined whether a 2-week washout period prevented such effects in this trial. Furthermore, horses functioned as their own control by taking MNT readings prior to treatment. However, an increase in MNTs was observed in both groups. Therefore, the trial would have benefited from the use of a no-treatment control group to establish a greater understanding of the observed effects. Future research with larger samples or alternative within-subjects approaches is recommended to strengthen confidence in the findings. Methodological constraints also introduced potential bias. Complete blinding of the researcher was not feasible; although randomization and concealed algometer readings reduced risk, observer bias cannot be fully excluded [115]. Pressure algometry is a semi-objective measure and can be indirectly affected by the interpretation of behavioral responses [116]. Therefore, separation and blinding of the assessor and treatment provider would minimize the risk of bias and improve data credibility.

Although all horses were graded $<1/5$ on the AAEP lameness scale or free from diagnosed pathology, the absence of a formal assessment for pre-existing back pain or muscle hypertonicity is a limitation. While baseline nociceptive readings were established, it remains unclear whether the observed effects reflected modulation of existing dysfunction or a general physiological response, limiting generalizability to clinical populations. Body condition score has the potential to increase result variability, as greater adipose coverage

could distribute pressure differently, reducing its ability to reach the relevant underlying structures. Heavy horses have been described as having higher MNTs [91], although findings in humans are inconsistent, with some studies linking obesity to elevated thresholds [117]. Therefore, while it cannot be concluded, potential variability should be considered.

4.2. Further Research Recommendations

This trial highlights that current knowledge on equine acupressure for equestrian use is insufficient and is currently guided by human studies and anecdotal experience. Research in this area remains in its infancy, presenting a myriad of opportunities for further investigation. Future work should establish the optimum dosage, treatment frequency, and acupoint selection for managing equine back pain, as well as the duration of effect. Longitudinal studies with follow-up at closer intervals would help define treatment schedules and confirm how long increases in MNTs are maintained. Beyond MNTs, additional outcome measures such as spinal kinematics, veterinary pain scoring, and palpation would provide a more comprehensive evaluation of clinical benefit, as demonstrated in acupuncture research [75]. Studies in horses with diagnosed back pain are also warranted to justify the use of acupressure in clinical cases requiring veterinary or physiotherapy intervention.

5. Conclusion

These results highlight an immediate increase in the MNTs along the equine epaxial musculature following a single 10-minute treatment of manual acupressure compared to a sham treatment. They provide preliminary evidence suggesting the use of acupressure to decrease nociceptive response in horses immediately after treatment. A decrease in this response could indicate a lower sensitivity of the back, allowing better back kinematics, and possibly improved performance.

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Authors' Contributions

ARC – data collection, data analysis, paper writing. RB – supervision, paper review. SC – conceptualization, supervision.

Data Availability

Data supporting the findings of this study can be obtained from the corresponding author upon reasonable request.

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No funding was received for this research.

Conflicts of Interest

The authors declare no conflicts of interest.

Ethical Approval

Full ethical approval was obtained for the material within this manuscript according to guidelines set by The Animal (Scientific Procedures) Act 1986 and the Declaration of Helsinki. The study was approved by the Animal Welfare and Ethics Committee of Writtle University College (Ethics Committee Approval number: 1411). Written informed consent was obtained from the owners of the horses before undertaking the trial. All horses were assessed for lameness prior to the investigation, and they were introduced to any devices used throughout the trial.

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Colombian Criollo Equine Gallop Variations

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Abstract

Kinematics is a noninvasive technique for observing locomotion characteristics in equines and other species through video analysis. The present study aimed to identify the gallop characteristics of the Colombian Criollo horse and verify whether they exhibit a suspension phase through kinematic analysis. Horses were ridden and filmed from a lateral perspective while galloping along a five-meter linear trajectory during an official breeding event. Movement was analyzed via Windows Movie Maker® software, which enables the examination of 30 frames per second to observe the support and lift sequences of the thoracic and pelvic limbs throughout the trajectory. The data revealed 10 cycles of asymmetric gaits classified as marching, with an average speed of 2.29 m per second (SD = 0.64 m/s). The horses executed cycles consisting of anterior and posterior tripedal support (100%), anterior and posterior monopedal support (97.5%), diagonal bipedal support (95%), posterior bipedal support (87.5%), lateral bipedal support (30%), and quadrupedal support (17.5%). None of the sequences resembled the three-beat canter variations. They did not conform to the characteristic cross- or rotational four-beat gallop patterns, as the horses did not exhibit a suspension moment. Therefore, the Colombian Criollo horse's gallop is distinct from that of other breeds because of its marching nature and absence of a suspension phase.

Keywords

Biomechanics; horses; Colombian Criollo; kinematics; gallop; locomotion

1. Introduction

Canter and gallop are natural gaits performed by equines of different breeds. They are classified as asymmetric and leaping because of a suspension phase within their movement sequences. These gaits can consist of either three or four beats and are recognized as patterns of high-speed locomotion [1–3]. Like other natural gaits, gallop and canter exhibit subtle variations influenced by factors such as breed, aptitude, training, sport activity, and work or leisure purposes.

Canter is a three-beat, asymmetrical gait that includes five support phases and a notable suspension phase. The length of a canter stride can vary from 4.3 to 8 meters, with speeds ranging from 5 to 9 m/s, reaching 18 to 38 km/h in some instances. The canter can be classified as right- or left-led, depending on which thoracic limb is the last to lose ground contact prior to the suspension phase [2–5].

Gallop is a four-beat, asymmetrical gait that includes a suspension phase and five or seven support phases. It can be categorized as either transverse or rotational. The transverse gallop is the predominant type, characterized by an initial support phase that features a posterior monopedal stance on one side, followed by an anterior monopedal stance on the contralateral limb before suspension occurs. The rotational gallop starts with a posterior monopedal stance, where, before the suspension phase, the ipsilateral thoracic limb touches the ground. This gait includes a suspension phase that concludes the movement cycle and is categorized according to the last thoracic limb that makes contact before

the suspension occurs. The speed of these gaits ranges from 12 to 14 m/s, reaching up to 54 km/h, with stride lengths of up to 8 meters [2–9], making them the fastest equine gaits.

According to the Colombian Federation of Equine Associations (FEDEQUINAS), the gallop of the Colombian Criollo horse is characterized as a diagonal-paced gait with three distinct beats. This sequence begins with a pelvic limb support phase, followed by a diagonal bipedal support phase, and concludes with an anterior monopedal support phase, all of which are repeated cyclically [5,7]. Therefore, the objective of this study was to identify and describe the kinematic characteristics of the Colombian Criollo horse's gallop.

2. Materials and Methods

This study was reviewed and approved by the Ethics Committee on Animal Use (CEUA) of São Paulo State University "Júlio de Mesquita Filho" (UNESP), under protocol No. 0203/2021. All procedures complied with institutional guidelines and were conducted in accordance with current regulations on the ethical use of animals in research.

In this study, 40 healthy Colombian Criollo horses, aged between 36 and 48 months and undergoing training, were recorded while performing the gallop. The group consisted of 22 females and 18 males (*stallions*), and identification through the recordings was not possible. All horses had registration certificates and microchips issued by FEDEQUINAS.

Filming was performed during the Grade A national equine event in Chiquinquirá, Colombia, in August 2021, in an indoor environment with controlled lighting. The track on which the gait was evaluated was constructed of solid, compact wood, which enhances the resonance of the footfalls and facilitates the identification of timing by judges and spectators; for this reason, it is referred to as the "sonorous track." This structure is installed at ground level in a straight line, ensuring uniformity and remaining free of obstacles [9]. It measures 15 meters in length and 2 meters in width; in its middle third, a linear trajectory of 5 meters (*filming trajectory*) was marked. This track is officially implemented in all equestrian events endorsed by FEDEQUINAS. The camera used (*Sony Handycam HDR-CX405*®) was positioned perpendicularly and mounted on a tripod in a static position throughout the filming process (**Supplementary Figure 1**).

For inclusion in the experiment, prior to the test, each horse was evaluated and examined by veterinarians, who certified their health, in addition to the anti-doping test conducted by FEDEQUINAS. Horses with physical or locomotor abnormalities were excluded from the competition, which constituted the exclusion criterion. The horses, grouped by sex, were ridden by professional riders certified by FEDEQUINAS and performed a collective warm-up to demonstrate their gaits. This warm-up lasted 10 minutes, consisting of 2 minutes at the walk, 4 minutes in "trocha" (a characteristic gait of the Colombian Criollo horse), and 4 minutes at the gallop. Subsequently, each horse was individually filmed while performing the gallop on the sonorous track, resulting in a total of 40 video recordings.

Chronophotographic analysis was performed individually for each video using computer software (Windows Movie Maker®), which enabled frame-by-frame evaluation and fa-

cilitated the identification of at least two sequences (strides) with the same number and order of the support moments for each horse. Regardless of the number of supports identified, the criterion was established that, during the execution of the cycle, all four limbs must make ground contact and that the sequence be repeated at least twice for this identification. **Supplementary Figure 2** served as a reference. Subsequently, the sequences were recorded and graphically represented in Excel®, together with the total number of frames corresponding to the trajectory (**Supplementary Figure 3**).

To estimate the speed, the displacement of the body and its center of gravity relative to a reference point as a function of time were determined. In other words, it was based on the division of distance covered over time ($\text{speed} = \text{distance} \div \text{time}$) [8,9]. Speed was also calculated by counting frames per second divided by the standardized distance of 5 meters. Each frame corresponded to 0.033 s, and the footage was 30 frames per second.

Following the identification of the support moments in the trajectory, two identical and cyclic sequences of support moments were established for each horse. This approach aligns with the framework presented by Beck [8], wherein these support sequences constitute the cycle of movement characterized by the regular and repetitive execution of support moments. The systematic distribution of these support moments facilitates the auditory and observational recognition of traits such as beats, strides, and speed.

Gait cycles were categorized into symmetrical and asymmetrical types. A symmetrical gait is defined by a consistent repetition of support moments, which are generated by either the right or left limbs and progress with an equivalent contralateral repetition. For instance, in the trot, a right diagonal bipedal support is followed by a left diagonal bipedal support as the corresponding contralateral element, interspersed with moments of suspension. Conversely, the asymmetrical gait lacks the repetitive nature of equivalent contralateral support moments.

The gaits were also classified as marching or jumping. In marching gaits, the horses always have at least one hoof in contact with the ground during the execution of the cycle. In jumping gaits, they exhibit a moment of suspension [3,4,10], where the horse loses contact with the ground. After the gait cycles were identified and the variations presented by the horses in the gallop were classified, the sequences were organized into groups containing the respective number of animals according to the gait cycle performed.

3. Results

Cinematographic analysis revealed that 95% of the horses displayed a single type of gait throughout the trajectory, whereas 5% exhibited two different gait types (**Table 1**), indicating a transitional cycle. Frame-by-frame analysis identified ten variations of the gallop (A–J) (**Figure 1**), corresponding to ten distinct gait sequences.

The ten identified sequences in the locomotion of Colombian Criollo horses (A–J) were generally classified as marching and asymmetrical gaits, with an average speed of 2.29 m/s (**Supplementary Table 1**). In terms of gallop variation, groups A, B, and C presented three beats, whereas cycles D,

E, F, G, H, I, and J presented four beats. These data correlate with the canter and the racing gallop, showing similarities in timing—three beats for the former and four for the latter—although variations were noted in the support moments and beat patterns throughout the execution of the cycles.

For the analysis and description of these sequences, the subsequent monopodal support moment was used as the initial reference point for the corresponding cycles. Importantly, monopodal support in these sequences does not always coincide with the beats, indicating that the analysis can be conducted at any support moment due to the repetitive nature of the pattern. This approach further clarifies the description of the strides exhibited by the horses in each group.

The horses in group A showed a sequence with three beats in five support moments, with the left posterior monopodal support as the first moment of support, which marks the first beat (b); at moment two, the second beat (b), was performed during the left diagonal bipedal support and followed by the left anterior tripodal support; at moment three, the horses exhibited a left diagonal bipedal support resulting from the elevation of the left pelvic limb; and at moment four, they generated the third beat (b), which was supported by the right forelimb. The right anterior support, together with the anterior diagonal, generated the right posterior tripodal support and ended with the right anterior monopodal support, resulting from the elevation of the diagonal (moment five), thus repeating the cycle.

The horses in groups B and C exhibited a sequence similar to that shown by group A during the execution of three periods: the first with the left pelvic limb, the second with the left diagonal bipedal support, and the third marked by the remaining anterior support. However, when the sequence was displayed, seven moments of support were formed. The essence of marking the three beats was preserved, but the breakover provided by the support that constituted the cycle increased by two moments of support in each sequence. For example, anterior monopodal support at moment six was maintained when the left pelvic beat was marked at moment seven (in groups B and C), resulting in diagonal bipedal support. Thus, it is important to recognize that the presentation of the breakover in the sequence has multiple causes, as the horse adapts during locomotion by distributing weight in a balanced manner across the thoracic and pelvic limbs.

In the analysis of group D, the sequence comprised five moments of support and four distinct beats. The first beat (b) was initiated during left posterior monopodal support, followed by the second beat (b), which occurred during posterior bipedal support when the right pelvic limb contacted the ground. The sequences then transitioned to the left anterior tripodal support, where the third beat (b) was generated through contact with the left thoracic limb. Subsequently, the right thoracic limb marked the fourth beat (b), while simultaneously the right pelvic limb was lifted, thus generating the moment of right posterior tripodal support. In the final moment of support, right anterior monopodal support was observed, resulting from the elevation of the diagonal support.

SUPPORT SEQUENCES BY GROUPS (GALLOP VARIATIONS)

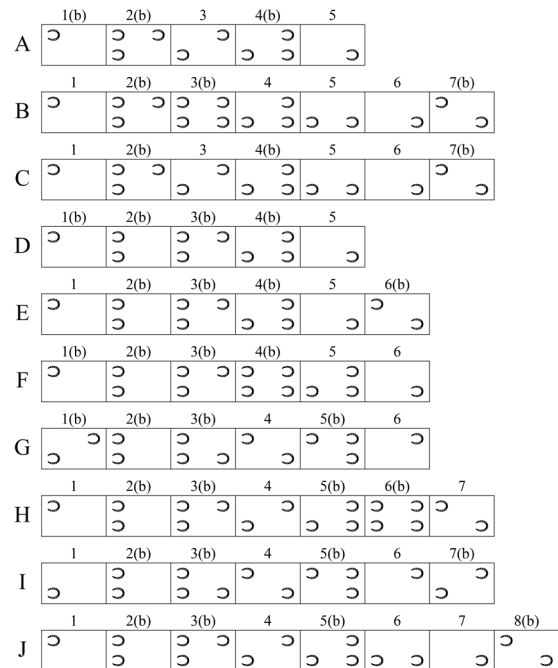


Figure 1: Steps by groups (A–J), showing the beats (b) and the number and type of supports displayed by the horses during the gallop.

Comparative analysis of group E revealed a similarity in the articulation of beats; however, a key variation was observed in the breakover presentation. Specifically, during moment six of Group E's sequence, there was sustained contact of the hoof from the right thoracic limb, whereas the left pelvic limb marked the following beat. This resulted in right diagonal bipedal support, a moment not observed in the Group D sequence. Consequently, this distinction resulted in the formation of a beat characterized by six moments of support and four beats.

The horses in group F exhibited a variation characterized by six moments of support and four beats. In contrast to the variation observed in group D, an additional moment of support was observed between the tripodal supports, specifically a quadrupedal support (moment four). However, the timing of the four locomotor limbs was similar to that of the horses in group D.

Group G was the only group that did not exhibit a moment of posterior monopodal support. Initially, a left diagonal bipedal support was observed, followed by the lifting of the thoracic limb and simultaneous support from the left pelvic limb, which constituted the second beat (b) and led to the generation of a posterior monopodal support. The third beat (b) occurred when the right thoracic limb was engaged at moment three. This was followed by continued right diagonal bipedal support. At moment five, the fourth beat (b) was indicated by the hoof of the left thoracic limb, which created a left posterior tripodal support. The sequence concluded with a left anterior monopodal support. The breakover of

this last support, noted at moment six, was first evidenced at moment one, where the hoof marking of the right pelvic limb was identified, indicating that it was not marked simultaneously by the diagonal support that formed the sequence.

The horses in group H exhibited a gait characterized by four distinct beats across seven moments of support. The initial moment involved the monopedal support of the left hind limb, which resulted from the elevation of the right thoracic limb during the seventh moment. This observation indicates that during this phase of support, the horse did not demonstrate a distinct beat. Following this, the first beat was produced by the support of the right pelvic limb, constituting the second moment of posterior monopedal support. The second beat subsequently occurred through the support of the left thoracic limb, resulting in left anterior tripedal support during the third moment. The elevation of the left hind limb then facilitated the establishment of left diagonal bipedal support, noted as the fourth moment. Following this arrangement, the right anterior monopedal support produced the third beat, thereby illustrating a right posterior tripedal support during the fifth moment. The fourth beat was generated by the support of the left pelvic limb, which, in conjunction with the other limbs, established quadrupedal support at the sixth moment. The subsequent elevation of the left diagonal bipedal support ultimately resulted in right diagonal bipedal support during the seventh moment.

The sequence observed in group I exhibited similarities to the cycle observed in group H. However, a notable distinction was the absence of a moment of quadrupedal support. Consequently, the fourth beat was not present during the sixth moment, unlike in group H, where the horse displayed this beat during the seventh moment of support with its right pelvic limb. This, in conjunction with the pincer-like support provided by the contralateral thoracic limb, resulted in a left diagonal bipedal support configuration.

In contrast, group J demonstrated a tempo comprising four beats over eight moments of support, with a sequence akin to that of group C. The critical difference was that the horse exhibited a moment of posterior monopedal support during the second moment, as well as at least one additional beat. This support was observed during the dissociation of the diagonal (simultaneous) bipedal support, a characteristic feature of the three-beat gallop.

Five percent of the horses exhibited two variations of the gallop within their trajectories, belonging to two distinct gaits for each corresponding group (A + E and D + F). This finding indicates that individual horses may display more than one type of sequence as a characteristic of their locomotion. Specifically, the horse that demonstrated sequences A and E in its trajectory transitioned from a tempo characterized by five support moments with three beats to a tempo with six support moments and four beats, respectively. Conversely, another horse presented sequences from groups D and F, which similarly transitioned from a tempo with five support moments and three beats to one with six support moments and four beats.

Table 1: Number of Colombian Criollo horses per gallop variation and the respective percentage of the total analyzed horses.

Gallop Variations	Number of Horses	Percentage
A	1	2.5%
B	9	22.5%
C	9	22.5%
D	4	10.0%
E	2	5.0%
F	9	22.5%
G	1	2.5%
H	1	2.5%
I	1	2.5%
J	1	2.5%
A + E*	1	2.5%
D + F*	1	2.5%
Total	40	100%

*Two horses exhibited two different gait variations within the trajectory.

The types of supports observed across the different groups from A–J, which represent the total number of animals analyzed, indicated an incidence of 100% for anterior and posterior tripedal supports, which were common across all gallop variations. Additionally, there was a 97.5% occurrence of anterior and posterior monopedal support; a 95% occurrence of diagonal bipedal support; a 30% occurrence of bipedal lateral support; an 87.5% occurrence of posterior bipedal support; and a 17.5% occurrence of quadrupedal support. Notably, anterior bipedal support did not influence the variations in the gallop sequences represented in **Supplementary Table 2**.

4. Discussion

Kinematics has facilitated the identification of variations in locomotion exhibited by Colombian Criollo horses during the gallop, corroborating findings reported by various authors in kinematic studies [10–16]. The observed variations in galloping were particularly notable in the sequence of supports, the number of support phases, stride duration, and footfalls, with ten distinct locomotion cycles identified in the gait of the Criollo horses. A predominant characteristic of these variations was their adherence to three- and four-beat patterns, akin to those observed in cantering and racing gallops [17].

According to the Fédération Équestre Internationale (FEI), the canter is a three-beat gait comprising six support phases. When cantering to the right, the sequence of footfalls is as follows: left hind limb, then simultaneously the right hind and left forelimbs, followed by the right forelimb. This is followed by a suspension phase, during which all four limbs are off the ground before the next stride begins [18]. This characteristic establishes it as a leaping gait. Similarly, the Portuguese Equestrian Federation defines the gallop as "a three-beat gait in which, in the right lead, footfalls occur in the following order: left hind, left diagonal, left fore, right

hind, and finally the right fore, followed by a suspension phase where all limbs are elevated before the initiation of the next stride" [19], thus elucidating the sequence of footfalls observed.

Dressage horses represent four distinct categories of canter, arranged in ascending order of velocity as follows: collected, working, medium, and extended canter. These categories differ not only stylistically but also in their execution speeds. According to the regulations set forth by the Fédération Équestre Internationale (FEI), the collected canter is characterized by shorter strides, whereas the extended canter features lengthened strides, enabling the horse to traverse the maximum feasible distance. By definition, a canter is classified as a three-beat gait, indicating that the diagonal limb pair makes contact with the ground simultaneously. The dissociation of the footfalls of the diagonal limb pair marks the transition from the canter to the racing gallop.

In the present study, the simultaneous support of a diagonal biped in groups A, B, and C characterized the three-beat variations. Furthermore, the dissociation of diagonal bipedal support was identified, wherein the horses exhibited separate limb supports, subsequently resulting in four-beat gaits in groups D–J.

The gallop of the Colombian Criollo horse is defined as a gait exhibiting a diagonal rhythm and three beats [5,15,20,21]. In this gait, the horse executes the first beat with a pelvic limb, the second beat is denoted by diagonal bipedal support, and the third beat is represented by the support of the remaining thoracic limb [15]. This rhythmic pattern was consistently identified in groups A, B, and C, which demonstrated three-beat cycles with identical execution but differing support phases; five support phases were observed in group A, and six support phases were observed in groups B and C.

The gallop of Criollo horses is characterized by a three-beat gait that demonstrates a diagonal rhythm. Nonetheless, if this rhythm is not executed properly, the horses may inadvertently adopt a four-beat running motion similar to that observed in horses from groups D–J. This shift could stem from various influences, including rider intervention or training, which could further explain the variation noted in the horses from groups A + E. This particular horse exhibited a three-beat gait with five support phases before transitioning to a four-beat cycle that integrated six support phases.

In *Chalanería Colombiana*, Londono [15] described the gallop cycle alongside its support phases. The initial phase consists of right posterior monopodal support, which is succeeded by right anterior tripodal support, then left posterior tripodal support, and finally concludes with left anterior monopodal support. Consequently, these support phases recur cyclically as the horses execute the gallop. Comparative analysis with the sequences mentioned above reveals that horses in group A exhibit similarities with the three-beat pattern and its corresponding support phases. Notably, this group also demonstrates an additional diagonal bipedal support phase interspersed between the tripodal supports, culminating in a cycle comprising five support phases.

In a comparative analysis of three-beat variations (A, B, and C) during the gallop in relation to the canter cycle [1–3],

group A presented the most pronounced similarity. This group demonstrated a three-beat cycle comprising five support phases, paralleling the canter cycle [1–4], albeit lacking a suspension phase. Conversely, groups B and C displayed one in which the three beats were generated by diagonal bipedal support, whereas the remaining two beats resulted from the respective forelimb and hindlimb movements.

The four-beat variations (D, E, G, H, I, and J) did not align with the characteristics observed in either the transverse or rotational racing gallops or with the four-beat gallop executed over six support phases [1–4]. The racing gallop in horses is primarily defined by monopodal support phases (hind and forelimbs) and bipedal support phases (hind, fore, diagonal, and lateral) [1,3,4]. Notably, the distinguishing feature of the four-beat cycles identified in this study was the inclusion of both anterior and posterior tripodal support phases, which are absent in the racing gallop [2,4,8,11]. The structure of these cycles was influenced by breakover-phase supports, thereby characterizing their unique composition.

Previous research has indicated that the transition from trot to gallop in equines occurs at speeds ranging from 3.7 to 4.7 m/s [22], with other findings reporting velocities of 5.0 m/s [23] and variations between 3.2 and 5.8 m/s [24]. These metrics are critical, as the trot typically results in lower speeds than the gallop does [13]. In the present study, an average velocity of 2.9 m/s was recorded (with a standard error of 0.64), which is below the velocities reported in prior studies. However, the average speed documented for the collected canter was 3.27 m/s, with measurements of 3.91 m/s for the working canter, 4.90 m/s for the medium canter, and 5.97 m/s for the extended canter [2]. The speed most closely aligned with previously reported values was that of the collected canter, which correlated with the velocities observed in Criollo horses.

In general, the observed cycles have been classified as ambling gaits [25–27], as no equine exhibited the characteristic moment of suspension [28–30], which was initially reported by Muybridge in his seminal work, *The Animals in Motion* [1]. Through detailed photographic analysis, he reported that during high-speed locomotion, equines demonstrate a moment when all four limbs are simultaneously off the ground, with no contact with the surface. This hypothesis has been substantiated across various species [1,2,7] and confirmed in equines performing three-beat and four-beat gallops [2,3,6,10]. Conversely, it has been reported that during the execution of a collected canter, equines do not exhibit a moment of suspension [2]. This characteristic, which is correlated with the observed velocity, suggests that speed may influence the occurrence of the suspension phase.

The three-beat cycles A, B, and C were classified as transverse gallops [1–4] because the equines initiated these cycles with monopodal support from the left pelvic limb and concluded with support from the contralateral thoracic limb. Consequently, these cycles are characterized as right-led gallops, as illustrated in Figure 1. In groups B and C, the final support phase was executed with breakover support from the left pelvic limb before the repetition of the cycle (moment 7).

The four-beat groups D and F were similarly classified as right-lead transverse gallops. Conversely, variations in

groups E, H, I, and J interfered with the breakover support during the final support phase, resulting in diagonal bipedal support. This complication hindered classification, as these sequencing patterns have not been previously documented. Finally, group G did not present the monopodal posterior support phase during the cycle, rendering its classification infeasible. Nonetheless, it is essential to clarify that the strides were executed sequentially by all four limbs.

Several studies have demonstrated that surface characteristics exert a significant effect on equine locomotion, modifying kinematic parameters and the expression of gaits. Factors such as firmness, elasticity, and traction influence stride dynamics, movement symmetry, and limb loading, with direct implications for the execution of locomotor cycles [31–35]. In the present study, locomotion was analyzed exclusively on a wooden track. It should be noted that the Colombian Criollo horses begin their training on this same type of surface, since the 'sonorous track' is standardized by FEDEQUINAS for competition. Consequently, it is recommended that future research evaluate and compare the locomotion of the same group of horses on different surfaces in order to determine potential similarities or divergences.

Some limitations of the study include that the same rider did not ride all of the horses, and certain rider-related characteristics, such as weight, preparation time, and riding equipment, were not standardized, which is likely associated with the variations that were observed. In addition, the number of frames used in the recordings was limited; therefore, future studies should consider the use of high-speed cameras to achieve greater precision in the analysis of movements. Furthermore, the integration of kinetic and kinematic analyses is recommended to provide a more complete, detailed, and precise biomechanical description.

5. Conclusion

The present kinematic study demonstrated that Colombian Criollo horses exhibit a gallop characterized by an asymmetrical ambling gait, lacking a suspension phase in the sequence of limb support. Moreover, the average galloping speed observed in these horses was significantly lower than the cantering velocities reported in other equine breeds.

Supplementary Materials

The **Supplementary Materials** comprises three figures and two tables: Supplementary Figure 1 illustrates the recording track and the perpendicular positioning of the camera during filming; Supplementary Figure 2 depicts the support moments; Supplementary Figure 3 provides a schematic overview of the methodology used for video analysis; Supplementary Table 1 reports the recorded speeds (m/s); and Supplementary Table 2 summarizes the incidence of support-moment types across the gallop variations.

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Author Contributions

Conceptualization: Hector García Duarte, Ana Liz Garcia Alves, Carlos Alberto Hussni, Marcos Jun Watanabe, Ricardo Costa Aranha. Methodology: Hector García Duarte, Daniel Parra-Torres, Heitor Cestari, Celso Antonio Rodrigues, Carlos Alberto Hussni. Preparation: Hector García Duarte, Carlos Alberto Hussni. Feasibility Data: Hector García Duarte, Carlos Alberto Hussni.

Data Availability

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

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Conflicts of Interest

The authors declare no conflicts of interest.

Ethical Approval

This project received ethical approval from the Ethics Committee on Animal Use (CEUA) of São Paulo State University "Júlio de Mesquita Filho" (UNESP), under protocol No. 0203/2021.

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Through Someone Else's Eyes: A Case Study of a Facilitator's View of the Perceived Benefits of Equine-Facilitated Learning (EFL)

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Abstract

Equine-Facilitated Learning (EFL) is a non-riding program that involves working with horses and relies on experiential learning for the client. EFL is used to facilitate increased awareness of individual consciousness by using equine-oriented activities to obtain positive outcomes, with emotional, social, physical, and cognitive goals. Current research suggests that EFL develops social skills and improves a sense of self in a range of clients from their own point of view. Given that client accounts may offer a limited perspective in some contexts, this case study explores facilitator insights to deepen understanding of EFL benefits. Taking an inductive approach, a single 2-hour semi-structured interview was conducted with an EFL facilitator who has owned and managed an EFL establishment since 2011. Thematic analysis identified three higher-order themes: emotional intelligence development, behavioral benefits, and the impact of the triadic dynamic: the facilitator, horse, and client. These themes further revealed the facilitator's perception that the client's emotional intelligence developed through mindfulness, introspective awareness, confidence, and empowerment, leading to behavioral benefits in both physical changes and socialization. Finally, the importance of the triadic dynamic highlighted the role played by both the facilitator and the horse in mirroring, creating a safe space, and signposting for the client. This study adds an additional aspect to the current body of scientific research on the role that the facilitator and horse play in achieving the positive outcomes described. Future research should aim to gain further perspectives from those involved in facilitating EFL and to enhance understanding of the role the horse plays in the EFL process.

Keywords

Human-equine dynamics; role of the horse; emotional intelligence

1. Introduction

Equine-Facilitated Learning (EFL) is a non-riding program that involves working with horses and relies on experiential learning for the participant [1,2]. EFL is used to facilitate increased awareness of individual consciousness by using equine-oriented activities to obtain positive outcomes with emotional, social, physical, and cognitive goals [3,4]. Current research suggests that EFL develops social skills and improves a sense of self in a range of participants, including adolescent offenders and both adolescents and adults experiencing poor mental health [1,5]. Participants can develop new perspectives on old problems by addressing preexist-

ing perceptions through equine interactions [6,7]. However, most research focuses on the impact of Equine-Assisted Interventions (EAI) on at-risk populations [1,8,9]. Given the positive outcomes reported in a range of participant groups, EFL may promote improved mental health and well-being for the wider population [10–12].

Well-being is defined as a state in which the individual realizes their own abilities, the normal stresses of life can be coped with, they can work productively, and are able to contribute to their community [13]. Poor well-being is a current national issue that leads to increased stress on health and well-being services; there has been a doubling in the rate of

self-reported work-related stress, depression, or anxiety per 100,000 since the coronavirus pandemic in the United Kingdom (U.K.) has been found [14]. This suggests that there is a need to explore alternative methods of improving well-being while balancing the challenges of increased demands on the National Health Service (NHS) and well-being organizations. Individuals with higher levels of self-confidence trust in themselves to successfully engage with the world, take on opportunities and new challenges, deal with difficult situations, and are ready to take responsibility when something goes wrong [15,16], which aligns with the definition of well-being. Partaking in sport and learning new skills and abilities are associated with the development of a positive sense of self [17], and the development of skills related to equine interaction can increase self-confidence through feelings of accomplishment [4]. It could therefore be argued that engaging in EFL activities aimed at promoting and developing self-confidence could be a factor in promoting well-being in the wider population [16,18,19].

There is extensive research available on the experiences of adolescents and adults with psychological problems or addictions who participate in EFL and EAI [2,4,18,20–25]. Participant accounts, however, may be limited and lack perspective, often due to a lack of self-awareness as well as a potentially limited ability to communicate effectively [26,27]. Interviewing the facilitator instead of participants allows researchers to identify gaps in the topic area, barriers that participants face, and best practice examples, to provide information on a wide variety of participants, and to offer a new perspective on EFL benefits for self-confidence [26,28]. This case study, therefore, aimed to explore the perceived changes and benefits of EFL from the perspective of a facilitator, including their role as a facilitator, and to consider the role of the horse in EFL.

2. Case Background

The participant (female) was the founder and manager of a U.K. EFL establishment, founded in 2011. The facilitator had previously engaged in EFL as a form of personal self-development during her previous public service role. The facilitator was qualified as an Equine-Facilitated Learning Practitioner through Learning through Exploration and Active Participation (LEAP) and adhered to its professional and ethical standards within the management of the organization. The center was purposively chosen due to the large variation in its clients: men and women aged 14 to 70 years old, who engaged in EFL for a variety of psychological and social reasons. The center was also affiliated with a charity working with youth offenders (two programs per year; with 28 to 30 men per program). The center welcomed 101 clients in 2023 (ranging from children in care or struggling at school with mental health challenges to adults struggling with self-confidence or mental well-being) and ran EFL sessions over the course of 10 hours per client over several weeks. According to the facilitator, the facility's remit does not include working with clients who have diagnosed psychological disorders. All clients complete a consent form that includes relevant medical and psychological history; however, no formal diagnostic assessment was conducted as part of this study, and the researchers did not independently verify the clients' psychological status. The center also provided workshops open to anyone, lasting between 2.5 and 3 hours, focusing

on building self-confidence, creating boundaries, and developing or increasing emotional regulation and emotional resilience. No incentives were provided for participation in the research, and written and verbal consents were obtained prior to the start of the interview.

Most studies on the benefits of EFL are qualitative and include single-case designs [2,29]. Case studies are defined as an in-depth exploration of a variety of different clients [30]. A case study approach is designed not only to promote debates and critical thinking but also to serve as the first step toward developing a form of evidence-based therapy [30,31]. In addition, the unique perspective of the facilitator provides multiple vantage points for evaluating the benefits, both short- and long-term, of EFL on a range of clients, drawing on seven years of experience as an EFL facilitator [2,32]. For the purposes of this case study, the facilitator was asked to reflect only on the benefits for adult clients wishing to improve their confidence and well-being but who do not suffer from any form of psychological disorder (e.g., bipolar disorder or severe/chronic depression). A semi-structured interview was used to collect data, allowing the researcher to further investigate the participant's responses by asking follow-up questions. Having guiding questions helps prevent the interview from straying too far from the central questions of the study [33,34]. An interview guide (see **Supplementary Materials**) was developed based on existing research and focused on addressing the facilitator's perception and understanding of EFL, her experiences with EFL clients, and the implications of EFL for clients' self-confidence [9,20].

The study was granted ethical approval by the Hartpury University Human Research Ethics Committee (ETHICS2025-4-LR). Participant information, interview recordings, and transcripts were stored securely in line with the University's Code of Research Practice (2020) and data protection legislation [35,36]. The interview took place in person and was conducted by SDJ, lasting one hour and fifty-one minutes, and was digitally recorded using QuickTime on a MacBook Pro (2010). The interview was recorded, transcribed verbatim, and anonymized prior to analysis.

The interview was transcribed verbatim, and the data were analyzed through inductive thematic analysis, identifying, analyzing, and reporting the themes found within the transcript [28,37,38]. Patterns, words, and phrases were written down and then grouped according to similar meanings [39]. The themes were organized in detail and interpreted in terms of social theory, moving from a description of events to a broader interpretation of their connotations [37,38,40]. The themes identified by the primary researcher were independently confirmed by the other author.

Consideration of the researcher's characteristics could influence the interpretation of the findings. The research team was composed of a student researcher and a member of the academic staff specializing in sports psychology and equestrian sport science. Both researchers have extensive equine backgrounds, and the latter author has experience working within EFL and EAT settings. While shared equine experiences between the interviewer and the EFL facilitator offered opportunities to build rapport during the interview process [41,42], care was taken during data interpretation to

ensure that personal bias did not influence the results. Collaborative efforts among individuals with varied experiences provided multiple vantage points for interpreting the data.

3. Case Analysis and Discussion

The case study interview identified three higher-order themes relating to the perceived benefits of EFL for clients from the perspective of the facilitator: emotional intelligence development, behavioral benefits, and the impact of the triadic dynamic (Figure 1). Each theme is discussed in relation to current literature and its impact on EFL practice.

3.1. Emotional Intelligence Development

The facilitator discussed emotional expression and the recognition of emotions to promote positive changes in EFL clients. How one perceives, regulates, uses, and understands their own emotions and the emotions of others is referred to as Emotional Intelligence (EI) [43]. Through an increase in self-awareness and self-perception, being in control of one's emotions is seen as a benefit in using one's interpersonal management skills [44]. People who experience difficulties in emotion regulation are likely to experience difficulties controlling and reducing emotional experiences and are

more likely to express negative emotions [45]. Stress-related challenges have been associated with dysregulation of biological systems, such as the hypothalamic-pituitary-adrenal (HPA) axis; although this study does not directly assess such mechanisms, it is possible that experiential learning approaches like EFL may support clients' perceived abilities to manage stress [46]. As psychosocial stress (life experiences) is one of the most common triggers of HPA axis dysregulation (which can lead to decreased self-confidence and negative experiences), it is recommended to use a biopsychosocial approach for treatment and prevention [46].

With the client developing an understanding of their emotions and how to recognize them, they are better able to perform (e.g., in sports or general life activities). Although more rigorous research needs to be done in the field of EI and the correlation between EI and its influence on stress, the preliminary findings indicate that those with higher levels of EI are better equipped to deal with stress, have more positive life outcomes, and experience better psychological well-being [47]. This study found that four specific lower-order themes reported by the facilitator could indicate the development of EI in clients of EFL: mindfulness, interoceptive awareness, confidence, and empowerment.

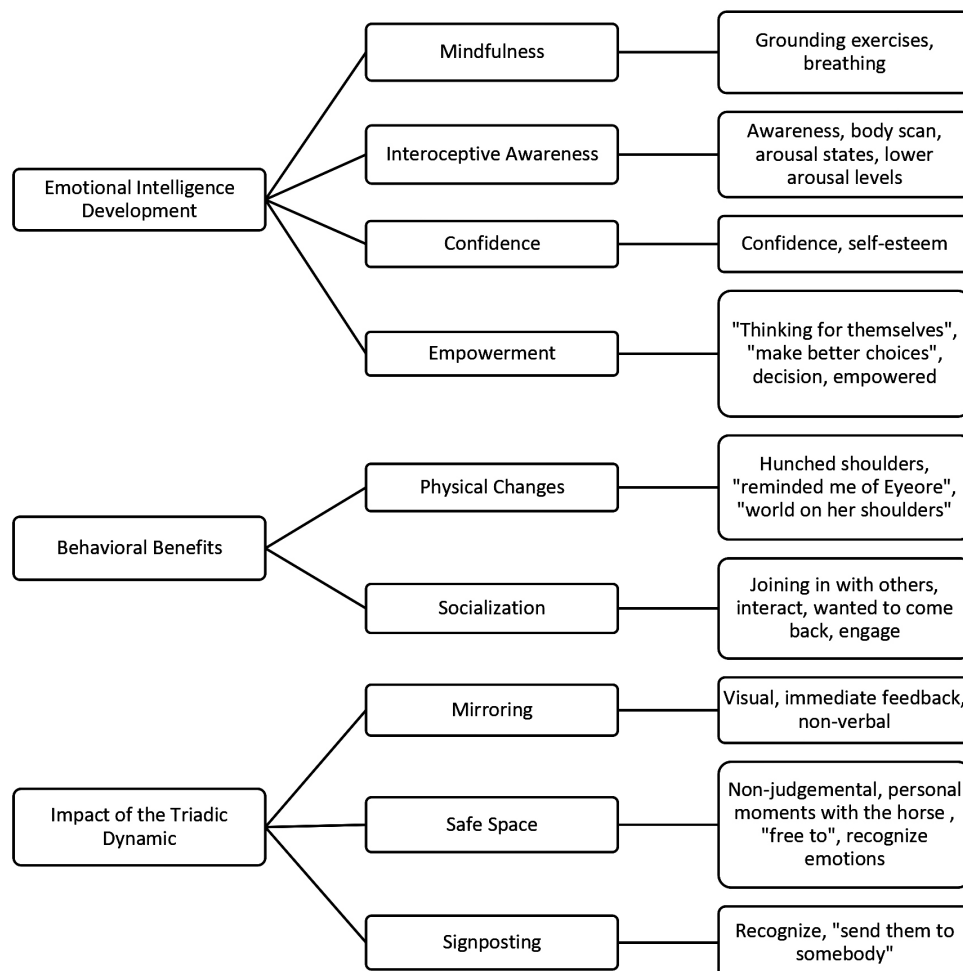


Figure 1: Higher- and lower-order themes.

3.1.1. Mindfulness

The EFL sessions begin with a body scan, a self-reflective exercise that focuses on helping the client become self-aware. This activity is defined as being mindful, in which the client is encouraged to intentionally pay attention to and nonjudgmentally accept feelings, sensations, and thoughts [48]. Afterward, a discussion takes place between the client and facilitator to acknowledge their emotions. Depending on how they are feeling, a specific exercise will be devised to achieve or overcome the objective or problem [49].

"Quite often they have default settings, but they do seem to remember the horse stuff, so they can refer back to it, and then they are better or able to deal with things as they arise."

Through participating in the act of mindfulness, the client can focus on skill-building and improving their mental well-being and resilience [50]. By having the mindful experience with the horses, clients can take away those experiences and see how they fit into their own lives [51].

3.1.2. Interoceptive Awareness

Having the ability to be aware of not only internal sensations within the body (e.g., hunger and pain) but also of emotional sensations is defined as having interoceptive awareness (IA) [52]. There are stated to be three stages of emotion processing: the first stage is the state of emotion, which can be executed and triggered subconsciously; the second is a state of feeling, which is represented subconsciously; and finally, the third is a state of feeling, which is made conscious [53]. There is an increasing recognition that the body and brain are coupled, which has aided scientific understanding of mental well-being [54]. It has been found that disruptions to this interoceptive system could contribute to a decrease in mental well-being [55]. When a client is not able to have effective IA, it has been suggested that these errors in interoceptive processing could be seen as biomarkers for different conditions [54]. With depression predicted to become the leading cause of disease burden by 2030, it is critical that opportunities such as EFL are presented to aid in improving mental well-being [56,57].

Through the development of IA, clients can work on recognizing and then self-regulating their emotions [58]. The facilitator mentioned that, to work with the horses, they would like the clients to sit at around 5 (out of 10) in terms of their arousal level. The arousal level can range from 0 (e.g., being asleep) to 10 (e.g., being extremely excited or anxious). By getting the clients to recognize their current arousal state, the facilitator can guide them through grounding exercises before proceeding with the EFL session [59].

"It's about managing people ... giving them the responsibility to manage their own states. If you feel yourself getting anxious, think of your anchor. Quite often when they go out and they're like 'something's happened' ... and then they anchor."

A variety of techniques are used, such as breathing, body scans, and anchors (something that the client thinks of that makes them feel good) [59,60]. By learning to recognize the signs of their arousal states and learning the techniques to self-regulate, the client can develop a better understanding

of the self and take these skills forward into their day-to-day lives [60].

The EFL facilitator identified that these skills are commonly developed by most clients over the course of their sessions. The facilitator discussed the clients' improved capability to recognize and understand why they were feeling a certain way, and how to cope with that, coping with anxiety and the unknown, learning to take a step back and break down the task when it was not working straight away (building blocks), changing their way of thinking, and changing their patterns.

"...for him to notice that when he's not stressed, the horses are happy to be around him, and it was like 'when I'm not stressed, people might like to be around me,' that kind of realization..."

It has been stated that higher levels of self-awareness lead not only to better decision-making and an understanding of one's own perception and thinking but also to the person becoming more authentic and confident within themselves [61].

3.1.3. Confidence

An increase in confidence is an attribute that the facilitator has often observed in their clients. The increase in confidence is relatively well documented within animal-assisted therapies (AATs) and sports coaching [44,49,62–64]. An increase in confidence is often seen due to the transferable life skills learned [65]. However, it has also been suggested that self-confidence could be situation-specific, meaning that a client might feel confident doing one thing but not another; this type of specific confidence is referred to as self-efficacy [66–68]. This contributes to behavioral change, and because self-efficacy expectations influence persistence, stimulation, thoughts, and behavior, it can be suggested that positive self-perception will lead to positive experiences [69].

"Doing this type of working with the horses... because they're big animals... it can be quite daunting for somebody... to go out in the field with a bunch of horses... just doing that is gonna boost somebody's self-confidence."

With clients experiencing positive outcomes in the tasks they undertake within the EFL sessions, it could be suggested that those building blocks discussed earlier are what help create the increase in confidence and, therefore, contribute to positive outcomes. With an increase in self-confidence, a positive behavioral change can be observed, and sometimes a change in the path the clients were following [49].

3.1.4. Empowerment

The facilitator highlighted the impact of the EFL sessions on the clients by recognizing the life changes they made as a result of their gained sense of empowerment. With confidence being an internal belief in one's abilities, empowerment aims to increase an individual's power and autonomy [70]. EFL activities are designed to encourage clients to make their own interpretations of what is happening within the session [71]. Often, the activities will be outlined with a simple instruction; it is then up to the client to conduct the activity in a way that they understand. They are asked to do what they think is right and are given the opportunity to think for themselves. When the horse responds to what the client asks of them, it helps build the client's feeling of empowerment—that they are capable of thinking for them-

selves and do not need to rely on everyone telling them exactly what to do [72].

"... it's just allowing yourself to consider the possibility that it can, you know, you can change, you're not stuck."

For some clients, this resulted in realizing that they did not want something anymore in their lives and made changes as a result. This was seen in the decisions around moving to another country or leaving long-term relationships that had not been working for a long time.

"The last I heard, she's (client) gone out to South America... it can be the difference between them carrying on as they were and... do something completely different with their lives."

The biopsychosocial model of health and illness was proposed in 1977 and has since been adapted as a potential model of well-being, stating that the psychological, biological, and social factors influence and interact with each other [73]. This indicates that each of these lower-order themes does not function independently but rather operates in conjunction with the others, with each factor exerting either a positive or negative impact on the rest [2].

3.2. Behavioral Benefits of EFL

The second higher-order theme identified was the behavioral benefits of EFL, followed by the second-order themes of physical changes and socialization.

3.2.1. Physical Changes

Clients were seen to become more confident in themselves when it came to asking the horse to do a certain task, or they would go from being a hunched-up person to bringing their shoulders back and smiling. There are a variety of studies that have looked at the impact of animal interactions on the physical characteristics of the clients. It has been suggested that 97% of family doctors agree that there are health benefits of owning pets, along with 71% of pet owners who are aware that pets improve mental and physical health [74]. From there, it can be suggested that this could be a reason why it is seen to improve mental well-being within EFL clients.

"She (client) really had the weight of the world on her shoulders... she reminded me of Eeyore. She came back about two weeks later; she absolutely bounced out of the car, completely different person."

Numerous studies have found that different emotions (such as anger, sadness, and happiness) can be identified correctly by looking at a person's gait [75–77]. The factors that play a key role in these perceptions are the amount of arm swing, heaviness of footsteps, and walking speed [78].

"She went from being this little hunched-up little person who was so down on herself to shoulders back, head up, big beaming smile, like 'YES, yes I can do this!'"

It has been suggested that changes in mood and confidence result in changes in body posture [78]. By being able to identify physical changes, the facilitator can gain a better understanding of the client and adjust the session to aid in the client's progression, which could result in a reduction in the number of sessions required without reducing the positive outcomes [79]. Studies that have looked at progression in psychotherapy due to feedback from the client have shown

clinically significant positive outcomes. In this scenario, the same could be applied, as the client gains a better understanding of self and develops self-confidence [80].

3.2.2. Socialization

One of the social benefits observed within EFL was the socialization aspect and the desire to socialize afterward. One of the clients was reluctant to participate in the session and was described as not wanting to interact with anyone and keeping to themselves [81]. This was further explained by the social worker, who advised that the client had been let down quite a lot in their life, which resulted in a lack of trust in others and themselves [82]. The interaction between the horse and the client, potentially through the role that the horse plays within EFL, led to a change. This change impacted how the client interacted with other people afterward.

"There was something that happened with her and the horse on the yard, and that interaction between them just really made a difference to her for that afternoon.... followed that up with the social worker, and she said... they have noticed a [positive] difference in her."

This further aligns with studies that have examined the impact of EFL and EAT on social interaction changes among clients. Although these studies have focused primarily on clients with intellectual and physical disabilities, this does not diminish the fact that similar changes have been observed in clients with low self-esteem as well [82], suggesting that EFL may positively influence clients' social cognition and behavior.

3.3. Impact of the Triadic Dynamic

The final higher-order theme identified was the impact of the triadic dynamic on client interactions (facilitator, horse, client), with the lower-order themes of mirroring, safe space, and signposting.

3.3.1. Mirroring

The facilitator discussed how they believe that horses can serve as an instinctive behavioral mirror, meaning that they are able to provide clients with immediate visual feedback about their behavior [2]. Practitioners in this field, as suggested by various studies [2,20,83], subscribe to the belief that working with horses decreases the likelihood of clients ignoring or avoiding the recognition of their own internal emotions (cognitive avoidance). Despite this effect not being empirically tested, it is considered a widely held belief within the field of EFL.

"She's talking about this guy; the horse just gets further and further and further away from her ... as far away from her as he could possibly get... [it could be suggested that] the clinginess pushed him [the guy] away and the horse just mirrored that and went to the end of the line."

The horse is believed to reflect what the participant is feeling. Through practitioner interpretation of equine responses to human body language, arousal states, and affective cues, the immediate feedback can be discussed with the client [84,85]. With the horse being a prey animal, it is believed by practitioners to be able to sense incongruence in clients and see it as a potential danger. To prevent the horse from perceiving it as a dangerous situation, the clients are required to recognize their own emotions and regulate them, intensifying

the client's sense of being present [21,86,87]. It has been suggested that instant feedback and nonverbal communication allow for establishing trust between the horse and client [4,88]. By promoting trust and instant visual feedback, the client is believed to be unable to engage in cognitive avoidance and is given the opportunity to address what they are seeing in the present moment. The added feedback from the facilitator is therefore critical to aiding in the client's development of self [89]. It is therefore important for the facilitator to be present during the sessions, as this helps the client gain a better understanding of themselves. This, in turn, allows for an increase in self-confidence and a decrease in stress, leading to an improvement in the client's overall well-being [90,91].

3.3.2. Safe Space

It is speculated that animals give less complex social signs than humans, and therefore create a reduced processing load, which could allow for a greater degree of social understanding and interaction [92]. Since the human-equine relationship is based on the development of mutual trust, positive interactions with horses provide a starting place for exploring and developing trust and relationships with another living being [2,93]. The facilitator highlighted the importance of the creation of a safe space to aid in the development and maintenance of that trust within the triad. As horses are not able to make a distinction regarding the client's religion, social, or racial standing, the client is simply a being, creating a nonjudgmental environment [11,94].

"...people give us tissues and stop us [from crying] ... because they can't deal with it. So a part of it [EFL] is allowing somebody the space, if they want to cry and howl and wail, then they can... once they're a bit more together, then we can kind of talk about it... it's really important to give people the space to emote however they need to."

By creating a positive learning situation, the development of learning and behavior results in the association of positive emotions and interpersonal management skills. The EFL sessions could therefore result in improved self-perception, leading to an increase in self-confidence [9,18,95,96].

3.3.3. Signposting

The facilitator discussed the importance of having the appropriate training to be aware of the support network available to direct clients to the correctly qualified professional if needed [97]. Signposting is an informal process, where information is given to clients to ensure they are being supported in a way that addresses their needs [98]. The clients are required to fill out a form, allowing for the opportunity to disclose any history or trauma; however, this information can sometimes be left out or misinterpreted. It is crucial for the facilitator to be able to recognize trigger moments during the sessions, making signposting an important factor to consider [99,100].

"Even though I am not qualified to deal with it [significant trauma], I'm able to recognize it and can send them to somebody who is."

It can be difficult for clients to contact new agencies, and it is therefore important that the facilitator takes the first step to recognize an issue (not diagnosing), and to signpost to the most appropriate agency [100,101]. By the facilitator helping to bridge the gap between the client and the refer-

ral, it can help instill confidence and encourage the ability to seek appropriate help [99,102]. This allows the client to contact the correct service rather than potentially being added to a waitlist for a service that is not able to help them in the first place [97].

3.4. Limitations

This case study was conducted based on the EFL Center owner's perception of the effectiveness of EFL. This position within the business could promote bias in the perceived benefits and improvements; therefore, there is no way of objectively assessing whether the participant's beliefs are true. Though the aim of the interview was to ask unbiased questions, the researcher was a novice in the field, and the framing of the questions could be reviewed for future research to ensure that challenges and negative experiences are also explored in more depth. As this study is based on a single case, it can only explore one participant's interpretation of the perceived impact of EFL on their clients. A further limitation is that client experiences were reported indirectly via the facilitator's reflections rather than through direct client accounts. While this approach was approved by the University's Research Ethics Committee and ensured that no identifiable information was included, it may have constrained the depth of insight into clients' perspectives and may carry implications when sensitive outcomes are described. Future research should take a qualitative, interview-based approach with a larger sample population of facilitators, both from similar backgrounds and those with diverse backgrounds and roles within an EFL business.

3.5. Future Research and Industry Recommendations

The present case study has offered a rare insight into the facilitator's perception, and as such, it adds a different point of view to current research surrounding EFL. Future research should address the limitations presented to aid in a broader contextual view of the perceived impact of EFL on clients. This would help strengthen the validity of the findings and contribute to a more comprehensive evidence base. Considering the role of the horse, which has been highlighted as crucial in this study, warrants further research to explore it in greater depth. This could offer insights into the perceptions that shape clients' experiences. Understanding the different human-equine dynamics across various contexts may enhance the current understanding of the horse's impact.

4. Conclusion

This case study explored the perceived changes and benefits of EFL from the perspective of the facilitator, their role as a facilitator, and the role of the horse in EFL. The outcomes of this case study demonstrate that EFL has a perceived positive benefit for the client, resulting in emotional intelligence development and behavioral benefits, which concur with the findings of other studies. It demonstrates the impact of the roles of both the facilitator and the horse, highlighting the environment in which EFL takes place. This case study adds an additional aspect to the present body of scientific research by suggesting that the roles of the facilitator and the horse play important parts in achieving the positive outcomes described. Future research should aim to gain further perspectives from those involved in facilitating EFL and to enhance understanding of the role the horse plays in the EFL process.

Supplementary Materials

The **Supplementary Materials** include the interview guide used in this study.

Authors' Contributions

Conceptualization, SDJ & ED; methodology, SDJ; validation, SDJ & ED; formal analysis, SDJ & ED; resources, SDJ; writing-original draft preparation, SDJ & ED; writing- review and editing, SDJ & ED; visualization, SDJ; supervision, ED; project administration, SDJ & ED. All authors have read and agreed to the published version of the manuscript.

Data Availability

These data are confidential and therefore not publicly available.

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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 (ETHICS2025-4-LR). The study complied with the guidelines of the Declaration of Helsinki.

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The Effect of Physical Activity on Cytokine Production: A Systematic Parallel Study of Horse and Human Athletes

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Abstract

Cytokines are glycoproteins responsible for cellular communication, influenced by exercise. Their levels vary depending on the intensity and type of physical activity in both humans and horses. This review aimed to assess the effects of various types and intensities of exercise on the production of pro- and anti-inflammatory cytokines. A systematic search (2000–2022) was performed using databases such as PubMed, Scopus, and Web of Science. Studies involving horses ($n = 3$) and/or humans ($n = 21$) undergoing physical activity were selected, resulting in 24 eligible articles. IL-6, TNF- α , and IL-10 levels increased after high-intensity exercise in both species, while moderate-intensity activity yielded more variable results. Some cytokines, such as IL-1 β and IL-17, exhibited species-specific differences. Cytokine production is influenced by exercise intensity and duration. The observed differences between horses and humans suggest physiological divergences, warranting further research in the field of exercise immunology and other related disciplines. As a potential outcome of this work, we propose that horses could serve as an appropriate translational animal model for human athletes in exercise immunology, justifying a more comprehensive comparative approach.

Keywords

Cytokines; pro-inflammatory cytokines; anti-inflammatory cytokines; physical activity; exercise; equids; human physiology

1. Introduction

Humans and horses have a unique relationship, not only due to their shared cultural and historical backgrounds, but also because of their natural athleticism [1]. This similarity has led researchers to consider the horse as a reference species for comparative studies in human exercise physiology, including immunology (both innate and under stress) and disease responses [2,3]. Conversely, knowledge gained from human medicine often serves as a starting point for research in veterinary exercise medicine [4]. The importance of exercise for both species is evidenced by the numerous studies exploring the production of cytokines involved in the response to moderate activity and/or strenuous exercise

[4–6]. These studies have demonstrated that oxidative stress during exercise is a physiological phenomenon common among exercising mammals [6–8].

The effect of physical activity on cytokine (interleukins; ILs) production has been an area of growing interest in recent years, with extensive research conducted in humans and a limited number of studies conducted in horses. Cytokines, a large family of intercellular signaling molecules, control immunological and inflammatory responses [9]. They are soluble glycoproteins that the body's immune and non-immune cells, organs, and organ systems produce and use to communicate with one another. Numerous cells can

produce cytokines, which typically act in tissues at extremely low concentrations in an autocrine or paracrine manner (**Figure 1**). Inflammatory cytokines, which comprise both pro- and anti-inflammatory mediators, are altered by various stressors, including physical exercise [10]. Localized inflammation is the typical physiological defensive reaction to initial tissue (muscle, joint, and connective tissue) damage [9]. The release of cytokines into the circulation due to a heightened response can be pathogenic, self-destructive, and occasionally lethal to the host [9].

Hypercytokinemia, also known as a cytokine storm, is a condition characterized by the systemic release of cytokines and is often referred to as the systemic inflammatory response syndrome (SIRS). Pro-inflammatory cytokine overproduction damages several organs and is linked to severe acute insults, including severe trauma, thermal injury, ischemia–reperfusion injury, septic shock, and systemic infections [11]. Moreover, physical activity can have varying effects on local and systemic cytokine production in both humans (athletes/obese, older/younger) and horses (athletes, younger/older, mares/foals), with the impact being dependent on the type of activity (aerobic/anaerobic) and duration (30 minutes to more than 6 hours) [2,12].

Moderate exercise helps maintain a healthy body weight, reducing the risk of obesity. In contrast, too little or excessive activity has been associated with chronic disorders such as diabetes, cardiovascular diseases, certain cancers, chronic respiratory diseases, and other serious health problems [13,14]. Additionally, individuals with highly inactive lifestyles frequently experience low-grade chronic inflammation, which often includes immunological components [15]. Regular exercise promotes the development of a balanced pro-inflammatory and anti-inflammatory environment in both younger and older humans [16,17] and younger and older horses [18,19], resulting in reduced basal inflammation and increased concentrations of both pro-inflammatory and anti-inflammatory cytokines [20–22]. It is thought that the recurrent acute inflammatory and subsequent anti-inflammatory cytokine responses after recovery from single bouts of exercise cause these long-term alterations in circulating cytokines [23].

Exercise elevates the levels of the pro-inflammatory cytokines IL-6, TNF- α , and IL-1 β in humans, triggering an acute inflammatory response [24–26]. Similarly, it has been reported to raise the systemic mRNA expression of TNF- α and IL-1 β in horses [27–29]. Overtraining, which is linked to muscle, skeletal, and joint injuries, is considered the primary culprit behind this exercise-induced inflammatory response in humans [30] and horses [31].

It is known that the type of activity that involves greater participation of different muscle groups, as well as the type of ergometer, generates different cytokine responses. The majority of the sport-specific interventions in humans included in this study were ergometer cycling, downhill running, various sports, and swimming. As a result of physical activity or exercise (at least 30 minutes/day), leukocytosis is commonly induced in humans [10,32–34] and in horses [10,35,36].

The cytokines released into the blood after exercise have received much attention in understanding the underlying

mechanisms of these events. Indeed, several studies [37–40] have consistently demonstrated that IL-1Ra, IL-6, IL-8, and IL-10 levels significantly increase after endurance activities (e.g., marathons) lasting from 1 to more than 24 hours. Excessive exercise may compromise the immune system. Although advancements have been made, many questions remain unanswered regarding the processes that link the types and levels of an individual's activity to immunological responses and illness. The impact of regular physical exercise on cytokine expression has yet to be thoroughly examined.

A brief overview of various cells expressing different cytokines is provided in **Figure 1**. The figure shows the different cytokines that are produced during exercise, their functions, and the pathways through which they act, showing the four main subsets of T cells (Th1, Th2, Th17, and TFH). Th1 cells secrete cytokines such as interferon-gamma (IFN- γ) and tumor necrosis factor-alpha (TNF- α), which promote inflammation and help fight intracellular pathogens. Th2 cells secrete cytokines such as interleukin-4 (IL-4) and IL-13, which help fight extracellular pathogens. Th17 cells secrete cytokines such as IL-17, which promote inflammation and help fight extracellular pathogens. TFH cells secrete cytokines such as IL-21, which help regulate the function of B cells, another type of immune cell that produces antibodies.

Comparative studies of cytokine production in humans and horses can provide valuable insights into the evolutionary and physiological basis of these responses, as well as their potential therapeutic implications for both human and veterinary medicine. By investigating the effect of physical activity on cytokine production in parallel studies of human and horse athletes, this study aims to contribute to our understanding of the immune adaptations to exercise and their potential implications for improving athletic performance and injury recovery in both species. In this review, we examined the impact of physical activity or exercise training on cytokines in humans and horses (adults, young, and obese). In general, the present systematic review supports the idea that exercise can stimulate both pro-inflammatory and anti-inflammatory cytokine responses.

2. Materials and Methods

2.1. Protocol for the Systematic Review

This systematic review was structured in accordance with the Preferred Reporting Items for Systematic Reviews (PRISMA) protocol (**Figure 2**). The Problem, Intervention, Comparison, and Outcome (PICO) model was used to formulate keywords and facilitate the literature search. The "P" (Population), which includes humans and animals focusing on horses; "I" (Intervention) is physical activity/exercise; "C" (Comparison) is a comparison between the trained group and the control group or between aerobic training and resistance training; and "O" (Outcome) is the effect of the training on the production of cytokine(s). This review is also based on a thorough systematic literature search of electronic databases for research examining the relationship between physical activity and cytokine production in humans and horses, published between 2000 and 2022.

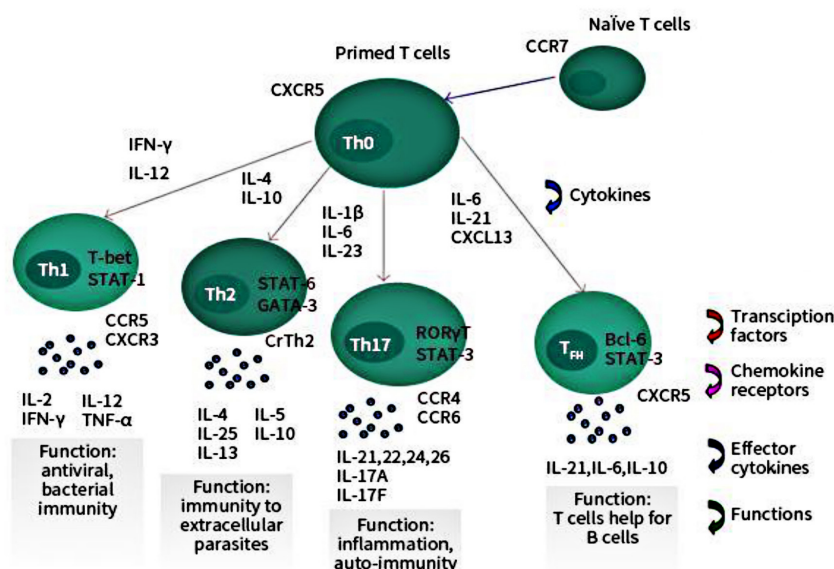


Figure 1: A schematic representation of different exercise-induced cytokine secretion, their functions, pathways, and effects. Naïve T cells, upon activation by an antigen, give rise to Th0, which differentiates into T cell subsets (Th1, Th2, Th17, and T_{FH}) that secrete different cytokines, thereby participating in various signaling mechanisms. Naïve T cell (CD4⁺): This represents an inactive T cell that has not yet encountered an antigen. Upon encountering an antigen-presenting cell (such as a dendritic cell) that presents an antigen to it, the naïve T cell gets activated. After activation, the naïve T cell becomes an undifferentiated T helper cell, commonly referred to as Th0. Th0 then differentiates into various T helper cell subsets depending on the signals it receives. Th0 can differentiate into Th1 under specific signals. Th1 cells express chemokine receptors CCR5 and CXCR3, allowing them to migrate to sites of inflammation. Th1 cells primarily secrete cytokines such as Interleukin-2 (IL-2) and Interferon-gamma (IFN-γ). IL-2 helps in the activation and proliferation of T cells, while IFN-γ stimulates immune responses against intracellular pathogens. Th0 also differentiates into Th2 under specific signals. Th2 cells express chemokine receptors CrTh2 and CCR4. Th2 cells secrete cytokines such as Interleukin-4 (IL-4), Interleukin-5 (IL-5), Interleukin-13 (IL-13), and Interleukin-10 (IL-10). These cytokines are involved in promoting allergic responses, activating B cells for antibody production, and enhancing the function of eosinophils. Th0 also differentiates into Th17 under specific signals. Th17 cells express chemokine receptors CCR6 and CXCR5. Th17 cells secrete cytokines such as Interleukin-17 (IL-17), Interleukin-21 (IL-21), and Interleukin-22 (IL-22). These cytokines play a role in promoting inflammation, neutrophil recruitment, and defense against certain bacterial and fungal infections. Th0 also differentiates into TFH under specific signals. TFH cells express the chemokine receptor CXCR5. TFH cells secrete cytokines such as Interleukin-21 (IL-21), Interleukin-4 (IL-4), and Interleukin-10 (IL-10). TFH cells play a crucial role in providing help to B cells within germinal centers, promoting antibody production, and facilitating the formation of memory B cells.

2.2. Eligibility Criteria

The study was carried out between 2000 and 2022. Only studies that fulfilled the following criteria were included:

1. Articles that were original and based on scientific research.
2. The reported study had an experimental design on human subjects, horses, or experimental/laboratory animals.
3. There was clear information about the training or exercise intervention.
4. The study investigated the levels of cytokines, either pro- or anti-inflammatory, or both, after an exercise or training intervention.

2.3. Information and Search Strategy

The databases included in the search were Scopus (<https://scopus.com>), SciELO (www.scielo.br), Web of Science (<https://webofknowledge.com>), PubMed (<https://pubmed.ncbi.nlm.nih.gov/>), and ScienceDirect (<https://sciencedirect.com>), using the terms: ("physical activities" OR "exercise" OR "training") AND ("cytokine production" OR "cytokine") AND ("human athlete" OR "animals horse-equids") AND ("2000–2022") as keywords. The search was conducted in October 2022 (first record). This search strategy identified 4,450 published articles (Figure 2). Two reviewers independently screened each article based on its title, keywords, and abstract to ensure that all relevant studies were captured.

The inclusion criteria were: English language, access to full texts, studies examining the effects of physical activity in experimental animals, humans, and horses/equids, and assessment of both pro-inflammatory and anti-inflammatory effects. After excluding duplicate studies, 24 studies were included in the review. A large number of studies (4,426) were excluded because they were not original scientific articles, there was no clear information on training or exercise interventions, participants were not healthy, they received medications in addition to physical activity, or the studies fell outside the search period (2000–2022). Studies included and excluded were reviewed separately by two researchers. The selected papers were then examined for methodological quality and classified based on individual levels of evidence.

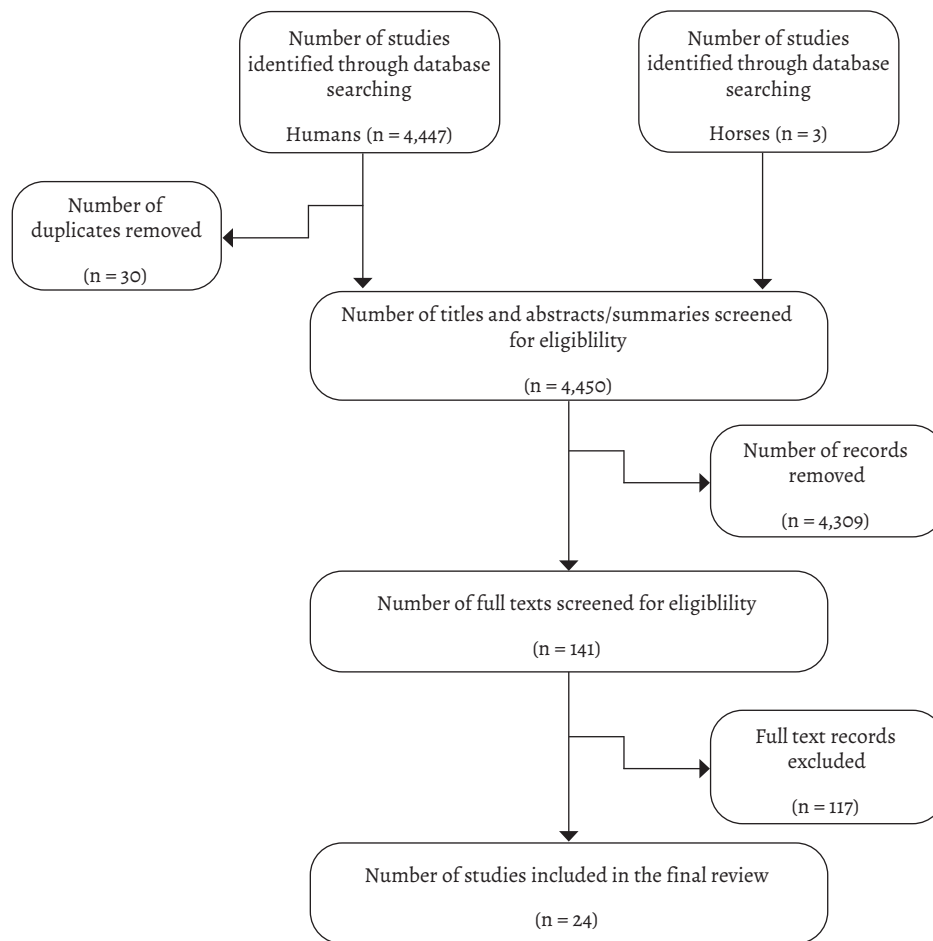


Figure 2: PRISMA flowchart for the process of selecting eligible articles.

2.4. Study Record, Data Items, and Outcomes

Information on the title, abstract, and keywords was acquired in the Research Information System (RIS) format and imported into Mendeley software, after which duplicate documents were excluded. The title and abstract were examined, and the inclusion criteria were reviewed during the article screening process. One author (IPO) analyzed the selected documents, excluding those that did not meet the inclusion requirements. Two additional authors verified the information (ASO and OCA). Data on the concentration of cytokines (pro- and anti-inflammatory) were obtained from the full text for reporting purposes. The Mendeley program was used to examine the exported keywords. Subsequently, data from Mendeley were exported in RIS format, including authors, titles, abstracts, and keywords.

3. Results

3.1. Quantitative Analysis

A total of 4,450 studies were identified after the search (after removing duplicates). Of these, 4,426 studies did not fulfill the eligibility criteria and were excluded. After applying the inclusion and exclusion criteria, 24 articles were deemed eligible for inclusion in this review. Three (3) studies focused on the effects of physical activity (exercise) on cytokine production in horses. In contrast, twenty (20) studies focused on the impact of physical activity (exercise) on cytokine production in humans and laboratory animal models, and one

(1) study conducted a comparative analysis between horses and humans.

3.2. Study Characteristics

The included studies (Figure 3) reported the effect of physical activity on pro- and anti-inflammatory cytokine levels. Of the 24 studies, six focused on laboratory animals (mice and rats), three on horses, and fifteen on humans. The human participants enrolled were between 18 and 81 years old, while the experimental laboratory mice were between 5 and 8 weeks old. The horse participants enrolled were between 3 and 8 years old. Participants from all 24 studies were generally healthy.

The exercise intervention was highly variable, ranging from resistance training to aerobic endurance, and from anaerobic endurance to various activities such as swimming, treadmill walking, and running. The duration of the exercise intervention was also highly variable, ranging from 4 days to 5 months. The studies collected blood samples at varying times (immediately, 30 min, and 1, 3, 6, and 24 h) after exercise (Table 1).

From the full texts, data regarding the study region were extracted and summarized. The majority of the studies were conducted in Brazil (n = 8), followed by Iran (n = 2), Japan (n = 2), South Korea (n = 2), and the United States (n = 2). Although relevant to the literature, no study assessed cytokine production using *in vitro*-stimulated immune cells.

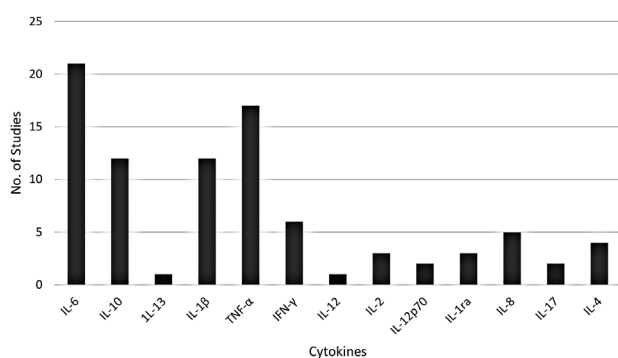


Figure 3: Number of references (n = 24) for studies on specific cytokines related to exercise in humans and horses.

3.3. Pro-Inflammatory Cytokines

A total of 24 studies were included after reviewing the articles (Figure 3). Among these studies, 12 examined the levels of IL-1 β [41–52], 17 examined the level of TNF- α [41–58], five examined the level of IFN- γ [51–59], one examined the level of IL-12 [59], three examined the level of IL-2 [50,52,54], 21 examined the level of IL-6 [6,10,25,41–48,50–54,56,57,60], two examined the level of IL-12p₇₀ [50,51], five examined the level of IL-8 [50,51,55,56], two examined the level of IL-17 [41,52], and one study examined the level of IL-12p35 [59].

3.4. Anti-Inflammatory Cytokines

Among the included studies, 12 examined the level of IL-10 [10,41,45,48–55,60], one examined the level of IL-13 [45], four examined the level of IL-4 [50,52,54,59], and three examined IL-1ra [10,44,50].

3.5. Effect of Exercise on Cytokine Production in Humans

Concerning IL-6 levels, lower values were reported in participants exposed to moderate-intensity exercise (921.3 ± 228.7) compared to those in the control group (1429.6 ± 270.4) [10,25,41,44,46,51] (Figure 4). Higher values were reported in participants exposed to high-intensity exercise (1364.0 ± 164.0) compared to those in the control group (901.8 ± 198.2) [10,42,50,57,58].

For serum IL-1 β levels, higher values were reported in participants exposed to moderate-intensity exercise (479.4 ± 4.0) compared to those in the control group (372.0 ± 5.0) [44,46,51]. Lower values were reported in participants exposed to high-intensity exercise (108.3 ± 41.7) compared to those in the control group (321.88 ± 48.0) [45,48,49].

For serum IFN- γ levels, no significant differences were reported in participants exposed to moderate-intensity exercise (42.6 ± 1.0) compared to those in the control group (43.3 ± 1.2) [41,53,54]. A similar result was reported for participants exposed to high-intensity exercise (1.4 ± 0.5) compared to those in the control group (1.5 ± 0.5) [50].

For serum IL-17 levels, no significant differences were reported in participants exposed to moderate-intensity exercise (3.4 ± 0.1) compared to those in the control group (3.5 ± 0.1) (Figure 4).

For serum IL-4 levels, no significant differences were reported in participants exposed to moderate-intensity exercise (4.8 ± 0.04) compared to those in the control group (4.9 ± 0.02) [54]. Higher values were reported in participants exposed to high-intensity exercise (4.9 ± 0.6) compared to those in the control group (3.5 ± 0.8) [50].

For serum IL-1Ra levels, no significant differences were reported in participants exposed to high-intensity exercise (0.03 ± 0.1) compared to those in the control group (0.04 ± 0.1) [10,50] (Figure 4).

For serum IL-10 levels, lower values were reported in participants exposed to moderate-intensity exercise (212.3 ± 7.7) compared to those in the control group (242.84 ± 8.16) [51,53]. Higher values were reported in participants exposed to high-intensity exercise (113.4 ± 37.0) compared to those in the control group (27.7 ± 25.3) [10,45,48–50,55].

For serum TNF- α levels, higher values were reported in participants exposed to moderate-intensity exercise (154.5 ± 1.0) [41,51] and high-intensity exercise (364.0 ± 60.0) [45,48,49,55,57,58], compared to those in the control groups (145.3 ± 1.0 and 228.0 ± 62.2 , respectively).

For serum IL-2 levels, no significant differences were reported in participants exposed to high-intensity exercise (7.6 ± 0.3) compared to those in the control group (7.7 ± 0.5) [50].

For serum IL-8 levels, higher values were reported in participants exposed to moderate-intensity exercise (54.5 ± 10.5) [43] and high-intensity exercise (83.3 ± 26.7) [10,50,55], compared to the control groups (27.5 ± 12.5 and 31.0 ± 24.1 , respectively) (Figure 4).

3.6. The Effect of Frequency and Duration of Exercise on Cytokine Production in Horses

Concerning IL-6 levels, higher values were reported in horses exposed to strenuous exercise (142.0 ± 5.0) compared to those in the control group (132.0 ± 4.1) [6,47,52] (Figure 5). For serum IL-10 levels, lower values were reported in horses exposed to strenuous exercise (226.3 ± 5.0) compared to those in the control group (236.6 ± 5.4) [6]. For serum IL-1 β , no significant differences were reported in horses exposed to strenuous exercise (41.8 ± 0.4) compared to those in the control group (41.1 ± 0.3) [47,52].

For serum TNF- α , lower values were reported in horses exposed to strenuous exercise (124.2 ± 0.5) compared to those in the control group (136.7 ± 1.8) [6]. For serum IFN- γ , lower values were reported in horses exposed to strenuous exercise (39 ± 1.2) compared to those in the control group (42 ± 1.5) [52,59]. For serum IL-17, lower values were reported in horses exposed to strenuous exercise (54.0 ± 1.5) compared to those in the control group (57.0 ± 1.5) [52]. For serum IL-4, lower values were reported in horses exposed to strenuous exercise (36.0 ± 0.5) compared to those in the control group (37.0 ± 0.5) [52,59] (Figure 5).

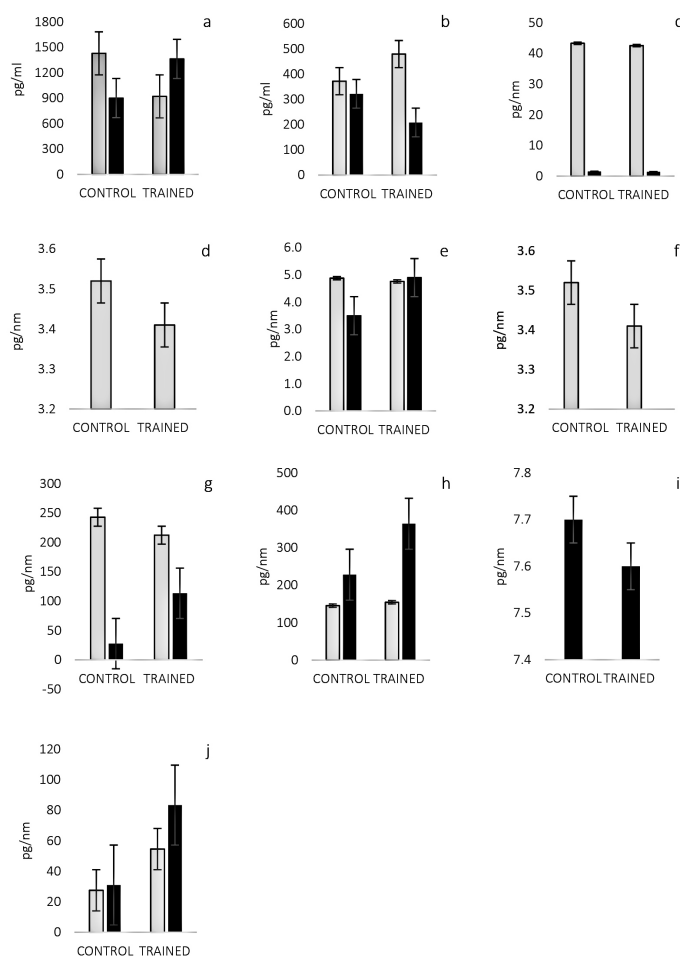


Figure 4: Human serum concentrations of (a) interleukin-6 (IL-6), (b) interleukin-1 β (IL-1 β), (c) interferon-gamma (IFN- γ), (d) interleukin-17 (IL-17), (e) interleukin-4 (IL-4), (f) interleukin-1Ra (IL-1Ra), (g) interleukin-10 (IL-10), (h) tumor necrosis factor-alpha (TNF- α), (i) interleukin-2 (IL-2), and (j) interleukin-8 (IL-8). Grey bars indicate moderate exercise intensity; black bars indicate high exercise intensity.

4. Discussion

The duration and intensity of physical activities have been reported to alter cytokine levels [61]. Additionally, moderate exercise loads reduce blood leptin levels, a hormone that helps maintain healthy calorie burning [62]. This adipocytokine, known as leptin, is known to increase IL-6 protein and its mRNA expression, thereby causing inflammation [12]. As a result, the data suggest that moderate exercise, such as treadmill training, lowers IL-6 levels. This finding is consistent with the study [62], which found that Zucker rats subjected to moderate but regular exercise experienced a substantial reduction in IL-6 compared to rats that did not exercise.

In contrast, the present review also found an increase in IL-6 levels among humans and horses involved in endurance training or marathons [6]—suggesting a possible cytokine response similarity between species. This could be because the IL-6 level in the bloodstream is significantly enhanced 30 minutes after the start of physical activity. In the selected articles, IL-6 concentration was measured immediately after the exercise intervention and not during the exercise. Thus, after running a 42 km marathon in humans or an endurance test for horses, the maximal IL-6 level was measured immediately afterward, showing a 100-fold increase. Although

more equine-based studies are necessary, the kinetics of exercise-induced IL-6 may be closely related to the duration of the exercise for both species.

It was also found that participants subjected to physical training for 2–4 km or performing aerobic training on treadmills for 30–60 min (moderate intensity) had an increase in IL-1 β , a pro-inflammatory cytokine. Moreover, a decrease in IL-1 β was observed in humans subjected to physical training of 42 km or endurance training on treadmills for 2–6 hours (high-intensity exercise) (Figure 6). In contrast, we reported an increase in IL-1 β in horses subjected to high-intensity physical training (Figure 7). These varying results may be due to species-specific differences in the immune system's response to exercise, with horses exhibiting a distinct pattern of cytokine production compared to humans [13]. Additionally, the type and duration of the exercise protocol used in the studies differ between humans and equines, which could contribute to the differing responses. Finally, the age of the horses and humans could contribute to the observed differences in the cytokine response. For example, older individuals exhibit a blunted cytokine response to exercise compared to younger individuals, which may have a greater impact on the IL-1 β response observed in the human study.

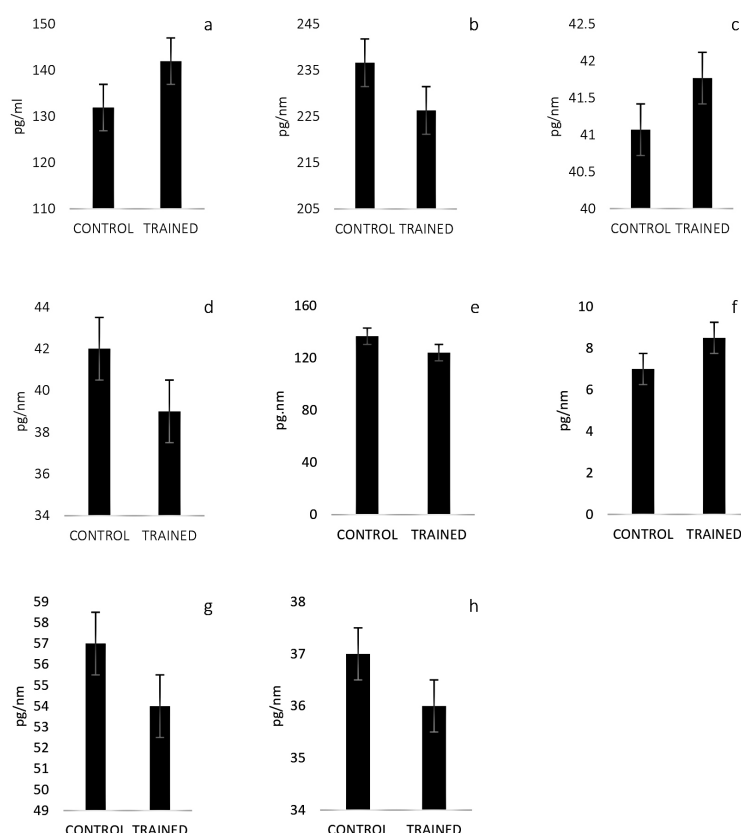


Figure 5: Horse serum concentrations of (a) interleukin-6 (IL-6), (b) interleukin-10 (IL-10), (c) interleukin-1 β (IL-1 β), (d) interferon-gamma (IFN- γ), (e) tumor necrosis factor-alpha (TNF- α), (f) interleukin-12 (IL-12), (g) interleukin-17 (IL-17), and (h) interleukin-4 (IL-4). Black bar: high-intensity exercise.

There were, however, no significant changes in the pro-inflammatory cytokines, including IFN- γ , IL-17, and IL-12, among all human participants and horses subjected to high-intensity exercise (**Figure 6** and **Figure 7**). However, there was a decrease in IL-17 among participants who underwent moderate-intensity exercise. The reduction in IL-17 levels among participants who engaged in moderate-intensity exercise could be attributed to several factors, including exercise duration and intensity. A subset of immune cells called T-helper 17 (Th17) cells primarily produces IL-17. These cells play a crucial role in regulating immune responses, particularly in the context of inflammation and autoimmune diseases. Moderate-intensity exercise has been associated with anti-inflammatory effects, while high-intensity exercise can lead to a more pronounced stress response and inflammatory state. The decrease in IL-17 levels observed in participants who engaged in moderate-intensity exercise could be indicative of the downregulation of Th17 cell activity. Another possible explanation is that moderate-intensity exercise promotes the release of anti-inflammatory cytokines and enhances the activity of regulatory T cells (Tregs). Tregs help maintain immune balance by suppressing excessive inflammation. The increase in anti-inflammatory factors and the regulatory activity of Tregs may counteract the production of IL-17, resulting in a decreased level.

In this review, an increase in anti-inflammatory IL-4 levels was also reported among participants exposed to high-intensity exercise (**Figure 6**). In contrast, there were no signifi-

cant changes in IL-4 levels among horses exposed to high-intensity exercise. The contrasting findings between humans and horses regarding IL-4 levels in response to high-intensity exercise can be attributed to several factors, as humans and horses have distinct immune system regulations and responses. IL-4, which is primarily associated with Th2 immune responses, may have different regulatory mechanisms in horses compared to humans. Secondly, the physiological responses to exercise differ between the two species. Humans and horses exhibit distinct muscle fiber types, energy metabolism, and aerobic capacities, which can impact their immune responses to exercise and subsequent cytokine production, including IL-4. Lastly, species-specific adaptations and genetic differences can lead to unique responses to exercise. Horses, which have been selectively bred for endurance and specific athletic abilities, may exhibit a different immune response profile compared to humans.

For the anti-inflammatory IL-1Ra level, which was reported only in human participants, there was no significant difference in the cytokine level among all participants involved in high-intensity exercise (marathon) (**Figure 6**). However, a decrease in IL-1Ra levels was observed among participants exposed to moderate-intensity exercise. The contrasting findings in IL-1Ra levels between high-intensity exercise (marathon) and moderate-intensity exercise among human participants can be attributed to the varying physiological responses and inflammatory processes associated with different exercise intensities. High-intensity exercise induces a

robust inflammatory response, leading to the release of various cytokines, including IL-1Ra, which acts as an antagonist to IL-1, a pro-inflammatory cytokine. During high-intensity exercise, IL-1Ra levels may remain stable or unchanged as the body releases IL-1Ra to counterbalance the elevated levels of IL-1. Consequently, no significant difference in IL-1Ra levels is likely to be observed among participants involved in high-intensity exercise.

In contrast, moderate-intensity exercise typically elicits a less pronounced inflammatory response due to lower mechanical stress and metabolic demands. The decrease in IL-1Ra levels among participants exposed to moderate-intensity exercise could be attributed to the relatively lower demand for IL-1Ra to counterbalance the inflammatory process. It is essential to acknowledge that individual variations and other factors may impact the observed cytokine responses, and additional research is required to fully elucidate the underlying mechanisms of IL-1Ra level changes in response to varying exercise intensities. There was no reported effect of exercise on the IL-1Ra level in horses, as no author reported this in any of the studies that passed the inclusion criteria. However, a study by [63] reported that after strenuous exercise in horses, the concentration of the cytokine IL-1Ra was reduced.

Physical exercise plays a crucial role in enhancing health benefits by increasing the production of IL-10. Interleukin-10 is a cytokine that plays a critical role, with potent anti-inflammatory properties, when produced during and after exercise. IL-10 helps the host's immune response to pathogens, preventing tissue damage. In this review, the findings showed that all participants involved in the marathon had an increased level of the anti-inflammatory cytokine IL-10 [10,49,50,55]. This could be a result of the magnitude of the exercise, as an increase in IL-10 levels is associated with active muscle mass and, therefore, exercise intensity in humans [64] (Figure 6). However, other exercises, ranging from swimming to squatting, either reduced IL-10 levels or showed no significant difference between the IL-10 cytokine level before and after the exercise. This data is consistent with the findings of the current investigation,

supporting the idea that the pattern and magnitude of the IL-10 response vary with the type of exercise. The IL-10 response in this study is similar to that previously reported by [13], who found that marathon training significantly increased levels of IL-10 in all groups relative to their baseline values (10–to 20-fold).

In contrast to humans, a decreased IL-10 level has been reported in horses, which may be a result of the prolonged training duration (5 months) in horses (Figure 7). This result is consistent with [65], who found that plasma IL-10 levels were significantly increased after 6 months of training in horses compared to baseline levels. The authors suggested that this increase may reflect a training-induced anti-inflammatory response that helps to maintain immune homeostasis in the horses [65].

TNF- α is a classic pro-inflammatory cytokine released in response to cellular damage. Low-intensity exercise in untrained individuals upregulates the body's inflammatory cytokine response, which is thought to increase with continued exercise, such as marathon running [66]. Fatigue and increased metabolic load work together to further activate circulating monocytes, causing them to generate and release pro-inflammatory cytokines [67]. Furthermore, cytokines released in peripheral tissues might exacerbate localized inflammatory pathways in muscles and joints, leading to an intensified systemic response. As a result, the extent of systemic elevations in TNF- α is related to the intensity, type, and duration of exercise [63]. TNF- α gene expression has been observed to increase for up to 24h after several exercise regimens (graded, interval, and repeated sprint exercise tests) in Standardbred mares. In this review, an increase in the TNF- α level was reported among humans and horses exposed to high-intensity exercise (Figure 6 and Figure 7). There was an increase in participants exposed to the treadmill (75% intensity VO₂), with reduced levels after 2 h. There was also an increase in the IL-8 level in all human participants, irrespective of the exercise type. These findings support previous studies [68,69]. Moreover, there was an increase in horses exposed to high-intensity exercise.

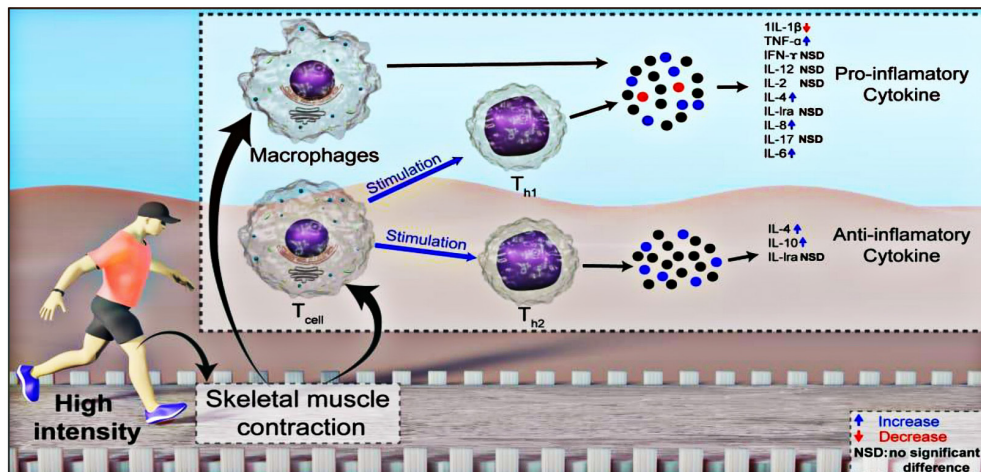


Figure 6: Cascade effect of high-intensity exercise on human skeletal muscle, cell stimulus, and cytokine production (increase, decrease, no significant difference).

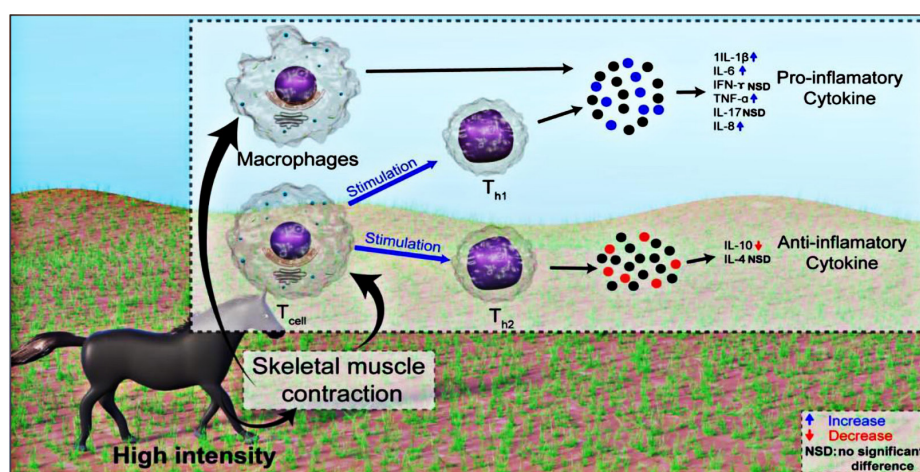


Figure 7: Cascade effect of high-intensity exercise on horse skeletal muscle, cell stimulus, and cytokine production (increase, decrease, no significant difference).

Peripheral blood mononuclear cells (PBMCs) can also be used in preclinical research due to their role in immune responses (i.e., diseases and inflammatory processes), including IL-6, IL-4, and IL-1β, more recently [6,59,70]. In horses, *ex vivo* stimulation of PBMCs with lipopolysaccharide (LPS) has been employed to assess cytokine production, showing significant increases in TNF-α, IL-1β, IL-6, and IL-8, which could be attenuated by treatment with silibinin [71]. Recent advances in monoclonal antibody development have enabled the quantification of mature IL-1β secreted by PBMCs following LPS stimulation, with CD14⁺ monocytes identified as the predominant cellular source [72]. Additionally, stimulation with PMA/ionomycin has been used to investigate TNF-α expression, demonstrating its production not only by monocytes but also by CD4⁺ and CD8⁺ T lymphocytes [70]. Collectively, these findings highlight the applicability of equine PBMCs as a robust *ex vivo* model for characterizing cytokine responsiveness.

Oxidative stress, mediated by the production of reactive oxygen species (ROS), is also a key regulatory mechanism of cytokine gene expression, primarily through the activation of transcription factors such as NF-κB and AP-1. In horses, recent studies have demonstrated this link, showing that antioxidant interventions can modulate cytokine responses under stress conditions. For example, astaxanthin supplementation in Thoroughbred racehorses reduced ROS formation and attenuated the exercise-induced increase of pro-inflammatory cytokines [73]. At the same time, treatment with chlorogenic acid decreased ROS production in immune cells, accompanied by an increase in IL-10 and a reduction in TNF-α, IL-6, IL-1β, and IL-8 [74]. Moreover, in immunization models for antivenom production, horses with stronger immune responses exhibited concomitant increases in oxidative stress markers and anti-inflammatory cytokines, such as IL-4 and IL-10, suggesting that redox modulation can influence cytokine profiles during adaptive responses [75]. These findings underscore the importance of considering oxidative stress mechanisms in conjunction with *ex vivo* stimulation data when interpreting cytokine production in horses.

Clenbuterol (β₂-adrenoceptor agonist) was evaluated for its effect on weight loss. Although it is prohibited in humans for anti-doping control, clenbuterol is popular in bodybuilding and physio-culture sports. The substance inhibits the inflammatory process. The cells from 14 untrained and 14 well-trained racehorses were collected after acute exercise and cultured with clenbuterol. The expression of CD4, CD8, FoxP3, CD14, MHC II, and CD5, in addition to IL-1β, IL-4, IL-6, IL-10, IL-17, IFN-γ, and TNF-α, was assessed. β₂-adrenoceptor stimulation led to enhanced anti-inflammatory properties in well-trained horses, as did low doses in untrained animals. In contrast, higher doses of clenbuterol created a pro-inflammatory environment in untrained horses [76].

The use of constant immunological markers to monitor cell and organ damage in advance of moderate- and high-intensity training is an area of ongoing research. While the development and implementation of such markers are still in progress, there is potential for both human and equine athletes to benefit from these tools in optimizing their training and performance. In the context of human athletes, various studies have explored the use of immunological markers to assess the impact of training, predict performance, and monitor the overall health status of athletes. For example, markers such as cytokine levels (including interleukins) and other immune cell parameters have been investigated to understand the inflammatory response and potential tissue damage associated with intense exercise [58]. By tracking these markers over time, trainers and athletes can gain insights into the training load, recovery patterns, and potential risks of overtraining or injury. In the field of equine training, similar investigations are being carried out to identify markers that can provide insights into the health and performance of horses. The focus is on understanding how exercise-induced stress, inflammation, and other physiological responses impact horses' overall well-being and athletic potential. While specific markers in horse training have not been mentioned in the provided context, ongoing research aims to uncover reliable indicators that can assist trainers and horse owners in optimizing training protocols and health management (i.e., kinship) [77]. Moreover, the use of the horse as a close model in translational studies to understand human physiology and immunity will shed light on preclinical and clinical trials [3].

Table 1: Summary of inclusion studies on exercise-induced cytokine production in humans and horses.

Ref.	Population, age, and location	Exercise and duration	Cytokines quantified	Biological sample and sampling time	Techniques
[41]	35 rats, 60 days, Brazil	Swimming, an aerobic and resistance training (moderate intensity) for 16 weeks	IFN- γ , IL-6, TNF- α , and IL-10	Serum, before and immediately after exercise	ELISA
[42]	43 overweight men, 25 years, Iran	Endurance training (aerobic running), resistance training, and concurrent training for 8 weeks	IL-1 β , IL-6, and TNF- α	Serum, before and immediately after exercise	ELISA
[60]	26 elderly women, above 60 years	Strengthening exercise, balancing, and walking exercise programs for 8 weeks	IL-6	Serum, before and immediately after exercise	ELISA
[43]	19 male, 23–25 years, South Korea	Treadmill for 1 hour at 75% intensity VO ₂ for 6 weeks	IL-1 β , IL-6, IL-8, and TNF- α	Serum, before and immediately after exercise, 30 minutes, and 2h after exercise	ELISA
[61]	Young male, 18–30 years, Canada	Eccentric exercise bouts for 4 days	IL-1 β , IL-6, and IL-10	Serum, before exercise, immediately after exercise, and 24h after exercise	ELISA
[53]	Male Swiss mice, 5–6 weeks old, Brazil	Progressive swimming for 5 days	IFN- γ , TNF- α , IL-10, IL-6, and IL-12p70	Plasma, before the exercise, immediately after exercise, and 3h after exercise	Cytometric bead array kit
[54]	12 elderly women, above 60 years, Brazil	Stretching, resistance, and isotonic exercise in circuits using weights for 16 weeks	IL-2, IL-4, IL-6, IL-10, IL-17, TNF- α , and IFN- γ	Plasma, before and immediately after exercise	Cytometric bead array kit
[44]	32 elderly women, above 60 years, Brazil	Aerobic, resistance, and stretch exercise at moderate intensity for 24 weeks	IL-1 β , IL-1Ra, and IL-6	Serum, before and immediately after exercise	ELISA
[45]	15 young males, 18–30 years, Brazil	Acute strength exercise (acute-SE) for 3 months	IL-6, IL-10, IL-1 β , TNF- α , and IL-13	Plasma, before, immediately after exercise, and 30 minutes after exercise	Bio-Plex Pro Human cytokine kit
[46]	28 rats, 8 weeks old, Iran	Endurance training and downhill running, treadmill for 8 weeks	IL-6, IL-1 β , and TNF- α	Serum, before and immediately after exercise	ELISA
[59]	11 horses, 4–8 years, USA	Strenuous exercise (Treadmill) for 10–12 weeks	IL-4, IFN- γ , and IL-12p35	DNA, before and immediately after exercise	Real-time PCR
[47]	8 horses, 3–4 years, Belgium	Strenuous exercise (Treadmill) for 1 month	TNF- α , IFN- β , IL-6, and IL-1 β	DNA, before and immediately after exercise	Real-time PCR
[48]	39 young Wistar rats, Minas Gerais, Brazil	Treadmill with high intensity for 6 weeks	IL-1 β , IL-6, TNF- α , and IL-10	Serum, before and immediately after exercise	ELISA
[49]	15 male Wistar rats, Sao Paulo, Brazil	Endurance training, Treadmill running for 8 weeks	IL-1 β , TNF- α , and IL-10	Serum, before and immediately after exercise	ELISA
[55]	18 master athletes, 53–64 years, Portugal	Marathon	IL-10, IL-8, and TNF- α	Serum, before and immediately after exercise	ELISA
[50]	16 male marathoners, Japan	Marathon for 8 weeks	IL-1 β , IL-4, IL-2, IL-8, IFN- γ , IL-10, IFN- α , TNF- α , IL-1Ra, TGF- β IL-6, and IL-12	Serum, before and immediately after exercise	ELISA

Ref.	Population, age, and location	Exercise and duration	Cytokines quantified	Biological sample and sampling time	Techniques
[51]	Male and female rowers	Water rowing workouts, running, and an ergometer for 8 weeks	IL-1 β , IL-6, IL-8, IL-10, IL-12p70, and TNF- α	Plasma, before, immediately after exercise, 30 minutes after exercise, 3 hours, and 6 hours post-training	Cytometric bead array human kit
[4]	8 trained male athletes, 25–28 years, and 8 trained horses, 6–8 years, Italy	Endurance races and training	IL-6	DNA, before and immediately after exercise	Real-time PCR
[52]	9 Arabian horses, Poland	Endurance training for 5 months	IL-1 β , IL-2, IL-4, IL-6, IL-10, IL-17, IFN- γ , and TNF- α	Serum, before and immediately after exercise	Immuno-enzymatic commercial assay for equine species
[62]	31 males, 24–26 years	Cycle ergometer	IL-6	DNA, before and immediately after exercise	Real-time PCR
[56]	22 male athletes, 22–25 years	Focused fitness for 5 days a week	TNF- α and IL-6	Serum, before and immediately after exercise	Linco Plex (ELISA-species-specific radioimmunoassay kit)
[63]	45 athletes/marathoners, average age of 25 years, USA	Marathon	IL-1Ra, IL-6, IL-8 and IL-10	Plasma, before and immediately after exercise	ELISA
[57]	15 male marathoners, 20–60 years	Marathon	Plasma TNF- α and IL-6	Plasma, before and immediately after exercise	Solid-phase, two-sided chemiluminescent assay on the Immulite system before and after the race
[58]	18 male, 19 years	Resistance exercise	IL-6 and TNF- α	Serum, before and immediately after exercise	ELISA

The incorporation of artificial intelligence (AI) can significantly enhance the analysis and interpretation of the gathered data in both human and equine contexts. AI algorithms can handle large datasets, identify patterns, and generate models that associate variables such as immunological markers, training protocols, physical conditions, and performance outcomes. This can facilitate sound evaluations, help predict optimal training strategies, and provide valuable insights into the complex interplay between immunological responses, training adaptations, and performance outcomes. In equine immunology, clustering and multivariate approaches have already been employed to capture immune dynamics. Principal component analysis and hierarchical clustering of 22 inflammation-related genes in peripheral blood leukocytes revealed distinct transcriptional signatures differentiating local and systemic inflammatory responses following LPS challenge [78]. Similarly, single-cell RNA sequencing coupled with unsupervised clustering resolved over 30 immune cell subpopulations in equine PB-MCs, including a predominance of T-bet⁺ B cells, thereby establishing a high-resolution immune cell atlas [3]. These findings highlight the feasibility of advanced clustering methods and suggest that their integration with machine

learning techniques may enable predictive modeling of cytokine-driven immune responses in horses. It is important to note that while the potential benefits of constant immunological markers and AI-based analysis are promising, further research, validation, and refinement of these approaches are still required before widespread implementation can occur. Moreover, as more data are gathered, the protocol can associate these variables and execute a large number of possibilities to produce sound evaluations. Nonetheless, the ongoing advancements in these fields hold promise for the future of training optimization, performance enhancement, and genetics in humans and horses.

5. Conclusion

The present findings suggest that cytokine levels, whether anti-inflammatory or pro-inflammatory, depend solely on the intensity and duration of exercise in both humans and horses. However, further studies are needed to compare these responses with immune system disorders and other exercise-induced cytokines. The use of cell-type-specific and longitudinal studies should be complemented by transcriptomic analysis to better determine their role in horse physiology, pathogenesis, and breeding.

6. Limitations

A significant limitation of this systematic review is the methodological heterogeneity in cytokine measurement approaches across the included studies. Studies varied in their analytical methods, with some quantifying mRNA expression in tissue samples while others measured circulating protein concentrations in serum or plasma. This distinction is critical because mRNA expression levels do not necessarily correlate with protein secretion due to post-transcriptional and post-translational regulatory mechanisms. The temporal dynamics also differ, with mRNA typically peaking earlier than the corresponding protein levels. Additionally, tissue-specific mRNA measurements cannot be directly compared to systemic protein concentrations, as local tissue expression may not reflect circulating levels.

Additionally, the lack of standardized timing for cytokine measurements significantly impacts the interpretation of results. Different cytokines follow distinct temporal release patterns that were not adequately captured in most studies. IL-6, for instance, typically peaks during exercise or within 30 minutes post-exercise and then rapidly declines, while TNF- α demonstrates a more delayed peak occurring 2–6 hours post-exercise. Anti-inflammatory cytokines, such as IL-10, exhibit biphasic responses, characterized by an early peak followed by a sustained elevation that can persist for over 24 hours. IL-1 β shows variable timing patterns depending on exercise intensity and duration. The majority of included studies measured cytokines "immediately after the exercise intervention rather than during exercise," creating several interpretive challenges. For cytokines that peak during exercise (such as IL-6), immediate post-exercise measurements may capture declining rather than peak concentrations, potentially underestimating the true magnitude of the response. Conversely, delayed-response cytokines might appear unchanged if measured too early, leading to false-negative results regarding anti-inflammatory responses. Single-time-point measurements cannot capture the dynamic interplay between pro- and anti-inflammatory responses, which is essential for understanding the complete immunological response to exercise.

Authors' Contributions

IPO: Conceptualization, literature review, data analysis, writing. ASO and OCA: Validation, review, and editing. EP and UYY: Literature review and critical review. MBM: Supervision, critical review, and final approval of the manuscript.

Data Availability

All data analyzed in this review are available in the published literature and are listed in the reference section.

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Conflicts of interest

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

Ethical Approval

This article is a systematic review and does not involve the collection of original data from humans or animals; therefore, ethical approval was not required.

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