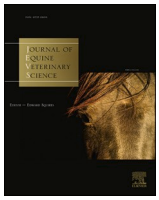
Journal of Equine Veterinary Science 158 (2026) 105801

Contents lists available at ScienceDirect

Journal of Equine Veterinary Science

journal homepage: www.elsevier.com/locate/jevs



Review Article

Riding with care: A review of factors that influence the welfare of the ridden horse and a case for the application of the precautionary principle in equestrian pursuits

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ARTICLE INFO

Keywords:
Equine welfare
Head and neck position
Rider factors
Riding equipment
social license to operate

ABSTRACT

Equestrian sport's social license to operate has come under scrutiny due to concerns surrounding the well-being of ridden horses. Inappropriate equipment use, such as harsh bits or overtight nosebands, can negatively influence well-being by generating inescapable pressure or pain on the sensitive structures of the horse's head and limiting natural behaviours. Restrictive equipment may also be used to generate exaggerated, stressful and uncomfortable head and neck positions such as hyperflexion. Saddles must be properly fitted to both horse and rider to ensure appropriate distribution of kinematic forces across the horse's back and promote the horse's comfort. The rider's balance, body control, ability to cue the horse, decision-making capabilities and understanding of equine behaviour can also influence the horse's experience under saddle. Physical health conditions such as ulcers or unidentified lameness can cause pain, stress and mechanical damage if left untreated, which may be further exacerbated by riding. The ridden horse's well-being is a multifactorial and complex equation. However, riders must seek to understand these nuanced aspects of well-being, and act on the precautionary principle (stating that a practice should not be assumed harmless until it is proven to be so) if there is not yet enough evidence on a subject to draw firm conclusions. Such directives will safeguard the welfare of ridden horses and the social license to operate for equestrian sports.

1. Introduction – social license to operate, precautionary principle and the horse's new role in society

Riding horses brings equestrians a strong sense of joy, purpose and satisfaction [1,2] and has been part of human culture for over 5,000 years [3]. However, the horse's role in society has largely shifted from 18th century views on total control of the horse as a tool to 20th century goals of achieving suppleness and agility through the "art" of equitation [4]. But with the horse's role in society having shifted so greatly, their experiences bear examining with a modern lens. Riding horses is no longer a necessity – it is a privilege. Horses are widely accepted as sentient animals with the ability to suffer and experience pain, fear and stress [5,6]. Because of this, equestrians have a moral obligation to investigate how their riding practices may be affecting their horses, both physically and mentally. By looking critically at the factors that can impact a horse's wellbeing during riding, equestrians can empower themselves to act in a way that is welfare-conscious and preserves the social license to operate (SLO) of equestrian sport.

Social license to operate represents the general public's perception of equestrian sport and the ethical and moral acceptability of it [7]. Equestrian sport has faced numerous public perception issues in recent years, in one case leading to a complete loss of access to sport for modern pentathletes [8]. The Fédération Equestre Internationale's (FEI) Equine Ethics and Wellbeing Commission reported that 65 % of the general public and 75 % of equestrian stakeholders have concerns about competition horse welfare and feel improvements need to be made [9]. This lack of public trust may be further bolstered by internet platforms, which have provided the public with near unrestricted access to equestrian culture and practices – both the positive and negative aspects. Such access has caused incidents of poor equine welfare to be publicized widely and rapidly by concerned stakeholders [10]. To rebuild and maintain public trust, equestrians must ensure they are conducting themselves in a compassionate and educated manner that places equine well-being at the forefront of all of their activities [7],

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https://doi.org/10.1016/j.jevs.2026.105801
Received 4 September 2025; Received in revised form 16 January 2026; Accepted 3 February 2026
Available online 4 February 2026

particularly ridden activities undertaken in the name of sport.

Such efforts may be fortified by the application of the precautionary principle, which proposes that one should not assume a practice is harmless until it has been proven to be so [11]. First presented in 1999 as a framework for environmental policy decisions, the concept of the precautionary principle has been applied to numerous other human practices with potential moral or ethical concerns. The principle is built upon four central components: taking preventative action in the face of uncertainty; shifting the burden of proof to the proponents of an activity; exploring a wide range of alternatives to possibly harmful actions; and increasing public participation in decision making [12]. Put simply, to implement the precautionary principle is to "give the animal the benefit of the doubt" [11].

In addition to implementing the precautionary principle, which focuses on unknown impacts of a practice, equestrians also must consider the known impacts that specific practices may have on their horses, both mentally and physically. The adoption of such a mentality in all aspects of equestrian pursuits can preserve SLO and promote a sustainable future for the equine industry. While there are many activities humans may take part in with their horses beyond simply riding, this review will remain focused on the experience of the ridden horse while under saddle.

2. Behavioural indicators of discomfort or distress in horses

The perpetual challenge of riding and training is learning to communicate with the horse without the ability to speak to them in a common language. As a rider hones their riding skills, they can communicate with their horse via physical and vocal cues that become associated with certain responses [6]. Through behavioural analysis, a rider can begin to understand what their horse may be communicating back to them in return.

Conflict behaviours are commonly used as indicators of negative affective states in ridden horses. Throughout this review, conflict behaviours will refer to indicators of negative affective states in ridden horses due to the adverse physical and/or psychological states such as pain, confusion, frustration or distress that have been associated with the expression of such behaviour [13,6,14]. These behaviours may be sudden and explosive, which can put riders at risk of injury [6]. Examples of conflict behaviours in ridden horses include bucking, rearing, bolting, spinning, kicking out, head tossing and evading rider aids [6]. These behaviours can arise when a horse is subject to pressure, pain, fear, stress, confusion, conflicting motivations, restrictive equipment or inconsistent and incorrectly applied training cues [13,6,14]. Such behaviours are strongly associated with ridden horses [15,16]. While a number of these behaviours are seen in free-ranging horses as well as ridden, [17] their expression under saddle is of particular concern as they suggest a state of negative affect that may be caused or exacerbated by human intervention, indicating a welfare concern.

While it is also relevant to seek indicators of comfort and positive affect in horses under saddle, such indicators are less well-understood within the literature. In many cases, both acquiescence to the rider's cues and the absence of behavioural indicators of negative affect in ridden horses are thought to be indicative of positive affect [18]. However, this should not be taken strictly as fact. A horse who appears complacent and is not demonstrating active conflict may simply be under such a high level of stimulus control that they do not act out against pain, stress, fear or frustration [19]. In more severe cases, such horses may be experiencing learned helplessness, causing them to shut down emotionally and physically after repeated exposure to inescapable unpleasant stimuli [19]. Certain restrictive pieces of equipment may also act as a form of physical restraint, preventing the expression of such behaviours even if the motivation to perform them is present [18,6]. Behaviour may be further limited by chemical restraint in the form of sedative pharmaceuticals (e.g., aceprozamine) used to increase tractability and reduce reactivity in ridden horses [6]. Additionally, most behaviours thought to indicate positive affect, such as approaching, grooming or otherwise making contact with handlers or conspecifics [18,20] cannot be directed towards a mounted rider or performed while under saddle. Positive affect may also be assessed via methods such as cognitive bias testing, human-animal relationship testing or time budget analyses, none of which can be accurately performed while a rider is mounted [20]. While certain physiological measures have been proposed as positive emotional indicators in horses, such as oxytocin and dopamine levels, a majority of such biological markers remain poorly understood in equine literature with conflicting results across studies [21]. For these reasons, identifying positive affect in ridden horses remains a greater challenge than identifying negative affect. While horses may also express neutral behaviours, they represent just 2.5 % of the equid social ethogram and are not as commonly displayed as agonistic or affiliative behaviour [22]. Human observers demonstrated the least agreement when identifying emotionally neutral responses in horses compared to positive or negative responses [23]. These challenges are what make the application of the precautionary principle so relevant to equestrian pursuits – if positive or neutral affect cannot easily be confirmed, a practice cannot be said to be harmless. Therefore, we must take preventative action in the face of uncertainty, in accordance with the precautionary principle's first tenant [12].

3. Equipment use

Every piece of equipment a horse wears has the potential to impact them both physically and mentally. A welfare-conscious rider must be aware of the potential effects of every piece of equipment they select to safeguard their horse's well-being.

Nosebands

Nosebands have been part of bridles for nearly 4,000 years [24] although their use is dependent on discipline or culture. When fastened correctly, nosebands are thought to stabilize the bit in the horse's mouth [25], though such an effect has been contested as supporting data is lacking [26]. When fastened loosely, the function of the noseband is merely cosmetic [27]. Because of this, some riders choose to only use nosebands during competitions, where they are expected or required in certain disciplines [28]. However, when over-tightened, nosebands can be detrimental to the horse's mental and physical well-being, causing stress and pain [29,27,30,28]. An overtight noseband can limit the horse's ability to open their mouth. This sensitizes the horse to bit cues by reducing their ability to gape at the jaw to evade strong forces from the bit or move their tongue to dissipate pressure [29,27,13,30–33]. Through such sensitization, a rider can conceal a lack of skill or a poorly trained horse [13,34,35].

Studies have found that both heart rate and eye temperature increase in horses wearing overtight nosebands even at rest, indicating a state of stress [36,34]. Overtight nosebands have also been found to decrease the expression of normal oral behaviours such as yawning, licking and swallowing [36]. Once the noseband is removed, a post-inhibitory rebound period of these behaviours can be seen, suggesting these horses are experiencing a state of deprivation while their noseband is fastened, which is inherently stressful [36].

Tight nosebands have also been associated with physical pain and tissue damage in horses. In a sample of competition horses, tighter nosebands were associated with increased prevalence of bit-related lesions in the mouth [25]. Studies have also identified bony changes in the skull at the site of the noseband in the form of palpable bone deposition [37,38]. This was noted in up to 82 % of horses in one sample [38]. It is not unreasonable to conclude that overtight nosebands have the potential to cause injury and tissue damage, as measurements of peak pressures on overtight nosebands have been found to meet or exceed those seen in human tourniquets [39–41]. In humans, nerve damage from tourniquet use can occur at just 50 mm Hg of pressure [42]. Despite

this, crank nosebands, a type of noseband that employs a series of rollers that make it easier to tighten, may exert up to 200-400 mm Hg of pressure on the horse's face [29]. In a study by McGreevy et al. [34], horses with overtight nosebands were found to have cooler facial skin temperatures, suggesting that tight nosebands do indeed restrict blood flow in the face. The pain and stress associated with overtight nosebands as well as potentially inescapable pain or pressure from the bit has the potential to result in conflict behaviours that can risk both horse and rider safety [13].

Despite a breadth of evidence suggesting that overtight nosebands can negatively influence the welfare of the horse, a recent study suggested that even highly tightened nosebands (0 cm between the noseband and the face) did not induce distress in horses [43]. While it would be tempting for many equestrians to take such findings as fact, instances like these provide an example of how the precautionary principle can and should guide our conduct as equestrians. As discussed by Wilkins et al. [26], this study contained a number of flaws within the experimental design including a low sample size of horses previously habituated to tight nosebands, the possibility of motivational conflict from food provision confounding results and a lack of applicability of results to the horse's experience under saddle. Decisions based on the precautionary principle should reflect the whole of our current knowledge, rather than a limited selection of studies that support one desired outcome. Should future results from more rigorous studies support the findings of Clayton et al. [43], it would be logical to re-evaluate these impacts. However, when employing the precautionary principle regarding noseband tightness, the majority of results thus far continue to support looser nosebands for the good of the horse.

Noseband type can also play a significant role in the experience of the ridden horse, not least because it impacts how easily a noseband might be overtightened or how the action of the bit may be strengthened [6]. Designs such as flash, drop or figure-8 nosebands contain straps that are fastened in front of the bit, making it more difficult for the horse to open their mouth even if the noseband is not overly tight. Conversely, plain cavesson nosebands, when fastened appropriately, are largely unobtrusive and are not thought to pose a threat to ridden horse well-being [27]. Studies have identified plain cavesson nosebands as the most common type of noseband used in North American and Australian equestrian communities [44,28]. In addition to the widespread use of the plain cavesson, a 2022 study of Canadian equestrians found that 71 % of nosebands were fastened appropriately with 1.5 cm ("two fingers") of space between the noseband and the frontal plane of the face [28]. However, a 2017 study of Danish equestrians found the opposite, with just 7 % of nosebands fastened appropriately [30]. These findings highlight the diversity of opinions and practices relating to noseband use in competition horses and suggest that regional differences may influence trends in noseband use.

The negative consequences of overtight or otherwise restrictive nosebands are well-studied and warrant significant consideration from equestrians when making equipment-related decisions. As of 2025, the FEI has introduced new protocols to measure noseband tightness at competitions using a standardized measuring device that is placed between the noseband and the frontal plane of the nose [45]. The standardization of measures like this illustrate how the precautionary principle can be applied in the horse industry for the good of both our horses and our social license to operate.

Bits

The mechanics, material and design of a bit have the potential to cause stress and pain to a horse regardless of what style of noseband they wear or how tightly it is fastened. The mouth is a highly sensitive organ, widely innervated to detect potentially damaging mechanical, chemical and thermal stimuli [46,47]. Bits can be made severe through design or application and therefore offer more control through their thinness, abrasiveness, topography, sharpness or the leverage they provide. Strong bits seek to amplify the horse's response to a rein cue via increased pressure that may result in pain [48,6] through compression and harsh manipulation of the oral tissues, inflammation, laceration and impeded blood flow [49]. Beyond the oral tissues, bits may also induce pressure or pain on the poll, chin or nose depending on their design [6]. These designs may also employ contradictory mechanics, such as gag bits that simultaneously cue the horse to move their head both up and down due to equivalent pressure on both the corners of the lips and the top of the poll. Such mechanics may prompt conflict behaviours as a result of stress, discomfort or inescapable pressures from the bit [6].

One common consequence of strong or inappropriate bit use is the development of oral lesions on the commissures of the lips and/or bars of the mouth [50–54,25]. When compared to unridden horses, horses ridden with bits and bridles demonstrated significantly higher levels of oral lesions [52]. A study of eventing horses identified acute oral lesions of the bit area in 52 % of horses following a cross-country test [53]. In racing thoroughbreds, approximately 53 % presented with lesions at the commissures of the lips [51].

Certain bit designs have been associated with increased oral lesions in horses, though all findings reported here are a result of convenience samples where the research teams did not have control over bit types used. In trotting horses, unjointed mullen mouth bits and straight plastic bits were associated with elevated risk of lesions compared to single-jointed snaffles or Dr. Bristol mouthpieces [54]. In Icelandic competition horses, curb bits with ports caused the highest incidence of lesions compared to snaffle bits or Icelandic curb bits (designed without a purchase component, only a shank) [50]. In eventing horses, thick (18-22 mm) or thin (10-13 mm) bits were found to increase lesion prevalence compared to medium-sized bits (14-17 mm) [53]. In the same group of eventing horses, double-jointed bits of all types were associated with lower incidence of lesions than unjointed or single-jointed bits [53].

In addition to lesions and tissue damage, bits and certain designs of nosebands are suggested to impair the horse's ability to breathe properly. Although the horse is an obligate nasal breather [55], the mouth still has a role to play in this biological function. There are three suggested mechanisms by which the bit may impact natural breathing in the horse: 1) breaking the airtight lip seal by forcing the lips to open around the bit or by the horse opening their mouth to escape bit pain; 2) retraction or movement of the tongue to dissipate bit pressure or avoid pain; and 3) flexion of the poll in response to bit pressure, reducing the angle of the throat [55]. This obstruction can result in breathlessness as exertion increases, an experience that can negatively impact performance and cause stress and discomfort [55].

Bitless bridles are often touted as the solution to the welfare issues surrounding improper bit use as they are perceived to be a more ethical alternative. Video analysis of behaviours of showjumping horses during competition found that horses ridden in mechanical hackamores demonstrated lower frequencies of aversive movements than a majority of horses ridden in bits [56]. In another sample of showjumping horses, there were no significant differences in rein tension used in a snaffle bridle versus a hackamore, suggesting at least an equivalent level of function while reducing the risk of oral pain or damage [57]. Horses participating in equine-assisted interventions who did bitted work had more negative reactions to a saddle test than those who worked bitless, suggesting increased negative associations with the bit [58]. A survey of horse owners found that horses ridden solely in bitless bridles were ranked by riders as more attentive than those ridden solely in bits [59]. Bitless riders report higher satisfaction with their mounts, with such riders describing better responsiveness and fewer hyper-reactive behaviours from their horses under saddle compared to bitted horses [60]. It is possible that these horses demonstrate increased rideability and tractability due to inherent personality traits that led their riders to feel safe choosing a bitless bridle for their mounts, rather than a direct effect of the bridle itself. However, it is notable that in Luke et al.'s study [60], bitless riders also demonstrated higher levels of learning theory

knowledge than those who rode in bits, and their horses had higher relative welfare scores in terms of management and health status, all of which may also positively influence the horse's overall riding experience. Qualitative work has found that riders who use bits often do so because of tradition or discipline-specific requirements, with a number of participants indicating they had never questioned why they ride with a bit – it was simply what was done [61]. As bitless riding is a non-traditional choice, riders who select these alternative methods may be more likely to question or reflect on industry standard practices and make decisions based on personal values rather than cultural expectations. This may influence their viewpoints on riding, competition and the human-horse relationship as a whole.

However, despite claims that bitless riding can improve well-being under saddle, not all bitless bridles are made equal. Research has found that sidepull designs of bitless bridles can result in pressures capable of tissue damage if sustained for long periods of time [41]. This study also identified avoidance behaviours from horses ridden in cross-under designs of bitless bridles. These horses demonstrated elevated and extended head and neck positions while under saddle, which can have negative long-term effects on both performance and musculoskeletal health [41].

There is still a relative dearth of research when it comes to understanding the full effects of the bitless bridle and various designs may impact horses differently. Like any piece of equipment, the bitless bridle requires specific training to the cues it provides, and like any equipment it is capable of being misused. However, current research suggests that certain designs of bitless bridles, when used appropriately, may offer a welfare-friendly alternative to traditional bits.

4. Head and neck position

A key focus of equitation is the rider's ability to control their horse's head and neck position (HNP). Certain equestrian disciplines such as dressage and western pleasure factor a horse's HNP into competition scoring [62,63]. However, recognition of the impact HNP can have on a horse's vision is rarely addressed. Horses naturally raise their head to help them focus better on objects in front of them [64] by making use of their binocular vision [65]. This is best demonstrated by showjumping horses, who display a higher HNP than seen in dressage horses [66]. It has been suggested that this elevated head carriage on approach to a fence helps the horse better assess and prepare for the obstacle [67,68]. Despite this, jumping horses are commonly fitted with devices such as martingales that seek to lower the horse's head position [69]. While the primary goal of such equipment is to restrict the horse's ability to evade bit pressure and maintain rider control while jumping, it also has the potential to restrict the horse's ability to see and assess the fence. This could impact stress levels and safety of both the rider and horse.

In contrast, dressage horses are commonly ridden with a lower HNP, which can result in horses being ridden behind the vertical [66]. When ridden behind the vertical in a rollkur position, the horse's vision may be severely restricted [70]. Horses ridden in rollkur tended to have stronger fear reactions than those ridden at or just in front of the vertical [15], potentially as a result of this reduction in vision. Being ridden behind the vertical, while commonly associated with dressage, can occur in other disciplines and is an inherently stressful and potentially painful experience for the horse [71]. This HNP has been found to induce behavioural problems indicative of reduced well-being under saddle, including tension, defensive movements and aspects of facial pain [71]. Preference tests of ridden horses have identified a significant preference for being ridden in a neutral headset (with the nose at or just in front of the vertical) compared to rollkur [15].

Lower HNPs may be generated using restrictive equipment such as side reins or draw reins [15]. However, these types of devices can lead to conflict behaviours [72] and are easily misused if an owner or rider is insufficiently educated [73]. Such misuse of aids to generate lower HNPs or "false frames" where the HNP is lowered without engagement of the topline and hind end can negatively impact both performance and equine well-being [74]. A recent meta-analysis of 58 studies on hyperflexion concluded that dressage training level, a horse's prior experience with hyperflexion, duration the position was held or the method of achieving the position did not negate the negative impact this HNP had on equine well-being [75]. Additionally, 65 % of studies found that hyperflexed HNPs had negative or no effects on performance, rather than positive effects as some proponents of this practice suggest [75].

Despite the demonstrated negative effects of such HNPs, these practices appear to be increasing in prevalence rather than decreasing [76]. While the FEI Dressage Judging Manual states that the nose should remain slightly in front of the vertical at all times [77], Lashley et al. [76] found that horses received higher scores for the piaffe the further behind the vertical their head was held. Hamilton et al. [78] also found nasal plane positions of up to 30° behind the vertical were associated with higher judge scores compared to nasal plane angles from the vertical to 30° in front of the vertical. These findings suggest that dressage judges are rewarding these HNPs in competition in direct opposition to the guidelines set out by the FEI Dressage Judging Manual, incentivizing such approaches rather than penalizing them.

While issues relating to rollkur or hyperflexed HNPs are most commonly researched and discussed in relation to dressage, such methods can be seen across a variety of disciplines in both English and western riding and present an equivalent welfare concern regardless of riding style.

5. Saddle fit

The act of horseback riding in any form requires significant movement of the legs, trunk and neck of the horse [79]. An effective rider must be able to absorb shock and impact from this motion through dynamic movement [79]. The saddle serves to facilitate these actions, providing the rider with support and stabilization [80] while distributing their kinematic forces across the horse's back, rather than through a single point of contact [81]. A properly fitted saddle facilitates a harmonious connection between horse and rider and serves to optimize athletic performance [82]. However, a poorly fitted saddle can present notable challenges to the well-being of the ridden horse.

Ill-fitting saddles can cause pain, stiffness, restricted movement, musculoskeletal injury, skin lesions, muscular changes and behavioural changes [83–89]. Pressures from poor saddle fit have been associated with back pain and potential tissue damage in horses [90,89]. Horses who were regularly ridden in such saddles showed increased behavioural reactivity when tacking up and were more likely to present with pain in their back muscles [91], suggesting anticipation of pain or discomfort related to saddling and riding. Despite the importance of a well fitted saddle, a high proportion of ill-fitting saddles have been reported in the general horse population, with one study identifying saddle fit issues in 38.1 % of a sample of 63 riding horses [84].

A properly fitted saddle should fit the rider as well as the horse. When a saddle does not fit the rider, it can impact the horse's ability to move comfortably and perform effectively [83,84]. This is because riders cannot sit properly with their heel, hip and shoulder aligned when riding in a saddle that does not fit them [92]. As a result, the even distribution of forces across the horse's back can be impeded [93–95,89], risking back pain and damage as highlighted above. Fitting a saddle to both horse and rider can become challenging, particularly when a rider is too large for their horse. In some of these cases, it can be impossible to find an appropriate saddle as the rider may require a seat so long it would extend past the horse's 18th thoracic vertebrae. This is largely considered unacceptable in modern saddle fitting as it puts pressure directly onto the lumbar spine – an area that lacks the support provided by the ribcage [96,87].

The rider may also negatively impact saddle fit through asymmetry, which is seen in a large number of equestrians. In a study by Gandy et al. [97], 83 % of riders demonstrated 30 degrees more hip rotation on their

right side compared to their left. An assessment of rider balance found that 37.3 % of riders sit crookedly on their horse [98], potentially inducing back pain or saddle slip in the horse. This was highly associated with a history of significant injury in the rider [98]. However, the authors note that saddle slip may also be the cause of rider crookedness, rather than vice versa. Horses have also been found to demonstrate asymmetry through the thoracic region, which could impact both saddle fit and rider position on the horse [99], as saddles are traditionally constructed to be symmetrical.

Saddle fitting is a challenging practice, hindered by a lack of regulation of saddle fitters worldwide. While many saddle brands will train fitters, each company has different standards for saddle fit without any overarching guidelines to shepherd the education of fitters across companies. This lack of standardized certifications and criteria for saddle fitters can make it difficult for horse owners to know who to trust when fitting a saddle to their horse [100]. In addition to a lack of regulation, there is a lack of science when it comes to saddle fit. Much of modern saddle fitting practice is based on tradition rather than peer-reviewed evidence [100]. Even among the Society of Master Saddlers, agreement on appropriate saddle fit is varied [101]. Further research is needed to understand how to optimize saddle fitting practices for equine health and well-being.

6. The role of the rider

Rider skill and physical ability

The skill level of a rider can have a significant impact on the mental well-being and physical performance of a horse under saddle. Advanced riders demonstrate better coordination, consistency, rhythm and connection with their horses [80,102] and more consistent posture throughout their trunk and limbs [103,104]. It is presumably due to this skill and control over their cues to the horse that these riders are able to exert greater influence over their horse's performance and generate more forward movement in the horse than inexperienced riders [105], who are less capable of independently managing their arms and hands while riding [106].

Factors such as core and limb strength, coordination and balance will all impact rider position and consequently influence force distribution across the saddle [107,79,105,108]. As discussed above, strong or improperly distributed pressures on the saddle can negatively impact the comfort, locomotion, health and performance of the horse. Advanced riders or riders with a higher level of personal fitness [109] may be less at risk of generating such pressures due to their improved balance. Conversely, an unbalanced [110] or asymmetrical rider [111] will increase the physiological demand of exercise on a horse.

Timing and precision of both training cues and their release following the desired response from the horse are key factors of effective training and riding [6]. The increased body control demonstrated by advanced riders therefore has the potential to positively impact clarity of cues, creating a more harmonious experience for both parties while under saddle. Depending on the complexity of a task, the rider's skill level and ability to enable the horse to perform can have a significant impact on the horse's success under saddle [112].

Rider size in relation to mount

Rider size in relation to their mount has the potential to impact the well-being of the ridden horse. Heavier riders have been found to transiently induce lameness at the trot and canter in some horses who were sound when ridden previously by a lighter individual [92,113]. However, heavier riders also struggled to sit properly in the test saddles, as all were too small for them [92,113]. This mismatch in saddle fit can make it difficult for larger riders to maintain a balanced position relative to the horse's centre of gravity [92]. Conversely, Christensen et al. [114] found that increased rider weight did not result in behavioural changes, increased stress or gait alterations. Studies of Icelandic horses found that although carrying heavier weight resulted in increased indicators of physical exertion and decreased stride length, the horses did not present with any lameness or back pain as a result of increased weight [115,116]. However, it should be noted that these studies [114–116] used lead weights on the rider's torso or in the saddlebag to increase weight carried by the horse, rather than naturally heavier riders as Dyson et al. [92] and Roost et al. [113] did. This may have eliminated challenges with saddle fit, which could have led to the differences in results, suggesting weight may be less of a factor in comfort of the ridden horse than relative size and saddle fit. Potential differences in the skill levels of the riders involved in these studies may have also contributed to variation in results. Experts have highlighted previously that the discussion of rider weight in proportion to their horse is only one part of the equation. There are many variable and interconnected factors that influence a horse's ability to bear a rider without incurring physical harm. These may be horse-based (fitness, strength, soundness, body condition score, size, age, locomotor ability, etc.), rider-based (rider size in proportion to horse, skill level, balance, personal fitness and locomotor ability, etc.), activity-based (duration, footing, environment, type of activity, etc.) or equipment-based (saddle fit to both horse and rider, type of saddle, saddle material and weight, noseband and bit selection, auxiliary rein use, etc.) [100]. Assigning maximum weights for individual horses to carry with no additional consideration for external factors is not an integrative or widely effective solution [100]. However, all equestrians should be cognizant of their size in relation to their horse and ensure they are selecting an appropriate mount.

A study of UK riders found that the average rider:horse bodyweight (RHBW) ratio was 12.5 ± 2.7 % [117], indicating that a majority of riders fall well within the commonly cited "20 % rule" – a guideline that suggests horses should not carry above 20 % of their total bodyweight due to the possibility of muscle soreness and tightness [118]. Just 0.8 % of riders in this study reported a RHBW ratio over 20 %, with the highest ratio reported being 21.88 %. This study also found that riders with higher rider:horse bodyweight ratios thought about their own weight and their horse's weight more frequently than those with lower ratios, suggesting these riders are indeed aware of and actively monitoring any potential impact that bodyweight ratios could have on their horse's well-being [117].

Rider education and psychological factors

Rider education also has a role to play in the experience of the ridden horse. A substantial number of conflict behaviours reported in ridden horses are suspected to be the result of unintentional neglect due to ignorance of the owner or rider [73]. While scientific guidelines have been produced for facets of management such as nutrition, housing and day-to-day care [119,120], training practices are commonly based on tradition, anecdotal evidence and historical practices rather than evidence-based findings [121–124]. Recent work found that nearly one-third-of horse owners lack fundamental knowledge on horse care and demonstrate the least understanding in the category of equine behaviour compared to categories of nutrition, health care, environmental needs or mental health [125]. Horse owners are extremely poor at distinguishing affective states in horses, particularly fear and anxiety which are often mislabeled as naughtiness or excitedness [126]. In particular, subtle indicators of negative emotions tend to be most frequently overlooked [23]. Even equitation scientists, equine behaviourists and veterinarians show poor agreement when defining behavioural indicators of stress [127,128]. A lack of understanding of equine behaviour could increase the risk of unfair or harsh handling and inappropriate punishment on the ground and under saddle. However, if even experts cannot agree on how to categorize equine experiences, consistent and accurate messaging and educational efforts cannot be effectively promoted to the industry at large.

In recent years, rider personality and mental state have been

identified as factors impacting the horse-rider dynamic under saddle. A handler's mental state and expressed reactions to external stimuli have been shown to impact fear and stress responses in the horse [129,130]. Wolframm and Micklewright [131] identified that leisure riders (who make up a majority of equestrians globally) are prone to experiencing more somatic anxiety than elite competitive riders. These leisure riders appear more likely to make judgements based on emotion [132,133], which may be inappropriate or subjective. Reactive, anxious or emotional responses to stimuli or horse behaviour while riding could generate conflict behaviour, potentially resulting in a negative relationship between horse and rider [112]. Conversely, handlers with positive attitudes were found to lower horses' heart rates while stroking them on the neck [129]. Handlers with positive attitudes and a higher level of confidence around horses could also lead a horse through an obstacle course more easily and with less lead rope tension than those with negative attitudes towards horses [134]. Positive attitudes and rider confidence levels can likely positively influence a horse's well-being while under saddle, highlighting the importance of an athlete's mental condition as well as physical.

The rider accounts for half of the equation when it comes to horseback riding. From skill, to size, to education and mental states, the rider can have a significant impact on their horse's mental and physical experiences. A responsible equestrian must be aware of their own shortcomings and seek to overcome them as much as they can for the sake of their horse. By building a training program that highlights both physical and mental strengthening, riders can promote a more positive riding experience for both themselves and their horses.

7. Conditions impacting the physical health, soundness and comfort of the ridden horse

Ulcers

Equine Gastric Ulceration Syndrome (EGUS/"ulcers") is common in ridden horse populations. Ulcers have been identified in up to 86–88 % of racehorses [135,136] and 53 % of leisure horses [137].

Exercise plays a key role in the development of EGUS. During exercise, pressures within the abdomen increase as the horse engages their muscles. Such pressures result in gastric compression which pushes stomach acid into the squamous region of the stomach. This can then lead to discomfort and ulceration [138]. As exercise intensity increases, so does the prevalence and severity of EGUS [139].

Competition in particular may put horses at an elevated risk of developing ulcers. In racehorses, mean gastric ulceration score was significantly higher in those who had raced within the last two months compared to those who had not [140]. In a population of horses kept under simulated race training, 100 % of horses developed moderate to severe ulcers within two weeks of the inception of the program. The ulcers remained present for the remainder of the 56-day trial [141]. After just five days of exposure to a simulated horse show environment (three days of riding and two days of trailering to and from a new location), 35 % of previously healthy horses had developed gastric ulcers [142]. During the competition season, 93 % of a population of high-level endurance horses presented with ulcers. However, this figure reduced to 48 % outside of the competition season [143].

In human athletes, comparable gastrointestinal conditions are associated with discomfort, abdominal pain and reduced performance [144,145]. Though the relationship between EGUS and pain in horses has not been studied extensively, it is a subject that has generated significant discussion amongst researchers in recent years and is anecdotally believed to be true by many people in the horse industry [146]. Recent work from Pineau et al. [147] found EGUS to be significantly associated with higher ridden horse pain ethogram scores, suggesting that ulcers may generate negative affect or pain. Horses with ulcers have also been reported to demonstrate self-mutilation, which has been associated with physical discomfort or psychological stress [148]. Additionally, EGUS is associated with girth sensitivity and overall sensitivity to touch, with improvement shown following treatment [149]. Ulcer treatment has also been reported by owners to result in improved performance and the elimination of kicking out, bucking, foot stamping and "spooky" behaviour under saddle [91]. These findings suggest a potential relationship between EGUS, discomfort and ridden conflict behaviours, which are associated with negative states of welfare [13,6,14].

Horses experiencing severe ulcers may also be subject to increased levels of psychological stress, with this population demonstrating higher levels of fecal cortisol metabolites in response to novel objects, suggesting an overall increase in stress sensitivity [150]. Riding horses are often exposed to novel, potentially frightening situations and environments, which can induce stress [151]. Therefore, it is reasonable to conclude that horses with EGUS may be more sensitive to such situations, particularly high-stress, novel environments such as horse shows or races. This may be a result of or a contributor to the high prevalence of ulcers seen in competition and racehorses [142,140,143,141].

While all aspects of EGUS are not yet well understood, it is clear that ridden work can play a role in the development of this condition and subsequent performance and under saddle experiences may be impacted as a result of it.

Unidentified lameness/pain

Lameness is referred to as the demonstration of an abnormal gait or stance likely indicating pain or injury [152]. Riding a lame horse represents a significant welfare issue. Asking a horse to continuously load painful or damaged tissues may lead to distress and the potential for further injury. Riding a lame horse is grounds for disqualification at a horse show and some disciplines such as endurance riding implement mandatory soundness checks at competitions [45]. Despite the equine industry demonstrating a high level of concern about riding lame horses [153], lameness is exceptionally common in the global population of riding horses. Studies have identified lameness in samples of the ridden horse population ranging from 50 % to 89.4 % [154–156]. As a result medical costs and loss of use, lameness is estimated to cost horse owners between $678 million and $1 billion USD annually [157].

This high prevalence of lameness may be attributed to the fact that horse owners demonstrate a very poor ability to identify lameness in their horses. When asked to simply identify a horse as "lame" or "not lame," owners disagreed with veterinary opinion in 82 % of cases [156]. Agreement levels were notably higher in cases of severe lamenesses (American Association of Equine Practitioners [AAEP] lameness score of 4 or 5/5; [158], with 85 % agreement between owners and vets in these instances [156]. However, owners were much poorer at identifying mild to moderate lameness. In a sample of 235 horses who were presented as "riding sound" and taking part in a regular riding program, 89.4 % were diagnosed with mild to moderate clinical lameness (AAEP lameness score of 1-3/5; [158] when assessed by a vet [155]. That these lame horses were presented as riding sound and were in regular work presents a significant welfare concern within the horse industry. If owners cannot accurately identify lameness in their horses, they are likely to continue riding and training horses who are not sound enough to be doing such work. Solutions to these challenges may be forthcoming in new technology such as inertial motion unit lameness detection systems or artificial intelligence machine learning models, which provide a more objective method of assessment.

Hoof care, conformation and shoeing

The phrase "no hoof, no horse" has been passed down through generations suggesting a keen awareness of the importance of hoof health and conformation when it comes to a horse's performance and welfare. Ireland et al. [159] found that issues with the hoof are the most commonly cited cause of lameness. Hoof conformation and condition can be influenced by a variety of factors such as nutrition,

environmental conditions and farriery regime [160–162].

Farriery and shoeing can significantly impact the experience of a horse under saddle. Shoeing influences the way a horse moves and loads the limb [163] and can cause morphometric changes to the hoof [164]. In some cases, these changes can risk the overall functionality of the hoof and increase the potential for lameness over time [165]. Toe grab horseshoes – shoes with small raised projections on the toe thought to improve grip – have been associated with increased potential for injury in racehorses [166]. Conventional horseshoes (terminating at the heel, attached with toe clips and four nails medially and laterally) were found to decrease heel expansion by 36.3 % compared to barefoot horses, suggesting a negative impact on shock absorption capabilities and natural hoof movement in these horses [167]. Beyond hoof impact, shoeing has been found to alter the concussion-dampening mechanisms in the distal limb including the loading of the coffin and fetlock joints [163]. Shod horses also experience higher amplitudes of impact vibrations on the hoof wall compared to unshod, despite comparable amplitudes of impact vibrations seen in the metacarpus [168]. Additionally, impact vibrations take longer to dissipate in shod horses than unshod [169].

This altered functionality may have implications for comfort and soundness of ridden horses. A study by Hockenhull and Creighton [85] found that shod horses were associated with resisting rider aids and slowing down, jumping issues and behaviours associated with discomfort while ridden compared to horses who were not shod. However, as this data was survey-based, it cannot be known if these reported behavioural challenges existed before the horses were shod.

The hoof is a sensitive structure with many receptors that provide proprioceptive feedback to the horse, allowing them to obtain information from the terrain they are crossing. These receptors can help with balance, as well as sensing pain and temperature [170]. By fitting a horse with traditional shoes and lifting the hoof off the ground, these receptors can no longer transmit information to the horse about the terrain they are navigating. From this, one could fairly assume that a horse's confidence, stride kinematics and ability to use the hoof properly when ridden may all be negatively impacted by the use of traditional horseshoes. However, the psychological impacts of shoeing on horses remains unaddressed in the literature at this time.

Nonetheless, shoeing may also be beneficial to equine welfare in certain cases. For example, corrective shoeing using toe or heel elevation can reduce strain on targeted tendons, ligaments, bones and joints in the hoof and leg during locomotion [171,172]. For example, for every 1° increase in the angle of the distal phalanx to the ground, force and stress on the navicular bone decreases by 6 % [173]. Such adjustments have the potential to increase comfort and soundness if targeted structures were previously overloaded due to a diagnosed condition (e.g., navicular syndrome, laminitis), the horse's conformation or natural locomotion patterns. However, such adjustments may also divert strain to other structures in the leg, potentially creating new mechanical challenges [171]. Shoe material may also play a role in efficacy, with Back et al. [169] finding that polyurethane shoes offered lower-impact accelerations and reduced friction with the ground compared to unshod horses, while steel shoes did not. Such kinematic improvements may reduce the risk of lameness and tissue wear over time.

Depending on riding discipline and training schedule, some horses may also experience a rate of hoof wear that exceeds their natural rate of growth. In these cases, shoeing can prevent discomfort and structural harm that may occur as a result of excessive wear, such as sole soreness [174]. Shoes may also be used to protect the sole from pain caused by riding on rough, rocky terrain by lifting it off the ground. Critics of traditional shoeing practices have suggested that hoof boots may serve the same purpose of preventing excess wear and protecting the soles while creating less impact on the structural function of the hoof [174]. However, preliminary research has also found hoof boots to alter gait biomechanics, increasing the stance phase of the stride and slowing deceleration and overall speed at the walk [175].

Regardless of whether a horse is kept shod or barefoot, appropriate hoof trimming on a regular schedule is also crucial to the welfare of the horse and their ability to work comfortably under saddle. A functional hoof should have a parallel hoof-pastern axis, a thick hoof wall, adequate sole depth, a solid heel base and growth rings of equal size below the coronary band [176]. When hooves are maintained with toes that are too long or short, sheared or underrun heels, uneven trims, cracks or other deformities, the horse may experience pain and discomfort both on the ground and under saddle [176]. Such issues can result in uneven loading and undue strain on the tissues of the hoof and leg, risking long-term injury.

Whether or not a horse should be kept shod or barefoot should be considered on a case-by-case basis, taking into account the horse's hoof conformation and health, veterinary conditions and soundness concerns, and the performance demands being placed upon them, both physically and mentally. These factors will all influence the horse's comfort, confidence and overall state of welfare under saddle.

8. Conclusion

Saddle fit and equipment use, restrictive riding and training techniques, rider dynamics and horse health and soundness are some of the most notable factors that can influence the well-being of the ridden horse. While more research is required to understand the full impact of certain factors on ridden horse welfare, acting on the precautionary principle will serve to safeguard the well-being of riding horses until stronger conclusions can be drawn. Traditionally, the burden of proof has been placed upon those advocating for welfare-focused rule changes and amendments to common practice. This required evidence of harm to be provided before change was considered, disregarding the possibility of unrecognized or unintentional harms caused by various practices. Through the application of the second tenant of precautionary principle, the burden of proof instead falls upon those seeking to resist change and uphold tradition. By increasing awareness of the impact the factors listed in this review can have on the physical and mental well-being of horses, riders can ensure they are participating in equestrian activities in an ethical manner while promoting the long-term sustainability of their horses and the industry at large.

Declaration of competing interest

The authors declare no conflicts of interest.

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