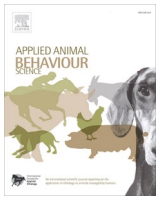
Applied Animal Behaviour Science 246 (2022) 105539

Contents lists available at ScienceDirect

Applied Animal Behaviour Science

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



New insights into ridden horse behaviour, horse welfare and horse-related safety

Karen L. Luke [a,*], Tina McAdie [a], Bradley P. Smith [a], Amanda K. Warren-Smith [b]

[a] Central Queensland University, College of Psychology, School of Health, Medical and Applied Sciences, Rockhampton, QLD 4702, Australia
[b] NSW Department of Primary Industries, Orange, NSW 2800, Australia

ARTICLE INFO

Keywords:
Conflict behaviour
Equestrian
Horse management
Hyperreactive behaviour
Riding
Training

ABSTRACT

Ridden horse behaviour problems are common and likely contribute to the dangers of horse riding. Emerging evidence suggests ridden horse behaviour problems likely signal poor welfare, however the relationships between ridden horse behaviour, horse welfare and rider safety, are yet to be fully elucidated. This study seeks to address this gap. Modern conceptualisations of animal welfare integrate physical wellbeing and affective state while recognising the dynamic nature of welfare status. Reflecting the latest understanding of animal welfare, the recently updated Five Domains Model emphasises the welfare consequences of husbandry and training practices. However, horse welfare assessment tools generally do not directly measure the ridden aspects of a horse's life. A survey was developed encompassing both husbandry and ridden behaviour to incorporate this expanded understanding of horse welfare. Underpinned by the Five Domains Model and existing welfare assessment tools, easily identified aspects of husbandry, health and horse behaviour were selected as animal-based welfare indicators. A relative horse welfare score was calculated based on riders' responses to each indicator. Additionally, riders reported their riding accidents and injuries incidences. Relative horse welfare scores were compared to ridden horse behaviour and rider accidents and injuries. Of the 427 participants, 94.4% were female, mean age was 44.3 years (SD 13.9), 49% were intermediate riders, 81% belonged to an equestrian organisation. The median relative welfare score was 71.0 (IQR 10.0) and 59% of horses performed one or more ridden hyperreactive behaviour in the previous seven days. Relative welfare score and rider accidents and injuries were significantly negatively correlated ($r = -0.37$, $p < 0.001$). Rider accidents and injuries were significantly postively correlated with ridden hyperreactive behaviour occurrence ($r = 0.34$, $p < 0.001$). Limitations included convenience sample and retrospective, self-report methodology. Despite this, the results consistently supported the hypothesis that horses with better welfare perform fewer hyperreactive behaviours and their riders have fewer accidents and injuries. Furthermore, the self-report nature of this study demonstrates it is possible to develop tools for riders that are sensitive enough to detect changes in their horse's welfare that may predict danger in the saddle. Equipping riders with such a tool could raise their awareness of the welfare impacts (positive and negative) of their horse care and training practices. Increased salience of horse welfare coupled with the recognition that horse welfare and human safety are connected, may encourage the adoption of practices that enhance the welfare of horses and likewise, their riders.

1. Introduction

Despite over five decades of research into horse-related safety, interacting with horses and horse riding remain dangerous (Acton et al., 2020; Barber, 1973; Kreisfeld and Harrison, 2020; Meredith et al., 2019; O'Connor et al., 2018; Pounder, 1984). In Australia, horses kill more people annually than any other animal (Gordon, 2001; National Coronial Information System, 2020) and for every rider killed, many hundreds more are injured. Recent Australian national statistics suggest about 2500 riders are hospitalised each year, with 24% of these having life-threatening injuries (Kreisfeld and Harrison, 2020). Reports from other continents such as North America and Europe suggest similarly high rider injury rates (Abu-Kishk et al., 2013; Acton et al., 2020; Ball et al., 2007; Meredith et al., 2019). Which riders are most at risk is unclear, but some evidence suggests it is young female riders (Acton et al., 2020; Chitnavis et al., 1996; Dekker et al., 2004; O'Connor et al.,

* Correspondence to: Central Queensland University, School of Health, Medical and Applied Sciences, Rockhampton, QLD 4702, Australia.
E-mail address: karen.luke@cqumail.com (K.L. Luke).

https://doi.org/10.1016/j.applanim.2021.105539
Received 24 November 2021; Received in revised form 20 December 2021; Accepted 22 December 2021
Available online 25 December 2021

2018), followed by older, experienced riders (Ball et al., 2007; Kruger et al., 2018; Meredith et al., 2018), while others found all riders to be at risk (Abu-Zidan and Rao, 2003). The most common cause of injury while riding is falling from horses (Ball et al., 2007; O'Connor et al., 2018), with several authors suggesting horse behaviour is responsible for many falls (Hawson et al., 2010; Warren-Smith and McGreevy, 2008), beyond that, little has been published.

While further investigation is needed to determine why horse riding is so dangerous, it is known that potentially dangerous ridden horse behaviours are common (Hockenhull and Creighton, 2013) and a suggested cause of rider falls (Ball et al., 2007; O'Connor et al., 2018). Ridden horse behaviours such as bucking, bolting, and spooking, are examples of hyperreactive behaviour that are often categorised as conflict behaviours (see McGreevy et al. (2005) for a comprehensive list of conflict behaviours and their definitions). Hyperreactive behaviour can arise from poor training that causes confusion or pain (meaning riders can inadvertently train their horses to be hyperreactive), or it can be a response to stress or pain caused by injury, ill-fitting tack, unbalanced or heavy riders (Borstel et al., 2017). Studies have also shown use of conflicting equipment such as spurs and harsh bits are related to hyperreactive behaviour (Condon et al., 2021). Irrespective of the cause, hyperreactive behaviour likely signals a welfare problem for the horse (McLean and Christensen, 2017; Ödberg and Bouissou, 1999). Despite this, hyperreactive behaviours are regularly misinterpreted by riders as misbehaviour or 'disrespect' and often result in harsher or more intense training, or in some cases euthanasia of the horse (Ödberg and Bouissou, 1999). Several authors have identified that misinterpreted horse behaviour is one of the most significant welfare issues facing horses (Hall et al., 2013; Horseman, 2017; Mellor, 2020).

The most recent update of the Five Domains Model (Mellor et al., 2020) represents an integrated approach to animal welfare that encompasses the three, broad philosophical approaches to animal welfare: animal health and functioning; minimisation of negative affective states, for example pain or stress; and allowing animals to live, as closely as possible, in their natural state (Fraser, 2009). Such an approach recognises that striving for optimal welfare in an animal is a complex, ongoing, dynamic process (Luke et al., 2022). Although some authors recognise that the ridden and husbandry aspects of a ridden horse's life are likely to be equal contributors to a horse's welfare (Borstel et al., 2017; McLean and Christensen, 2017; Mellor et al., 2020), currently no horse welfare assessment tool exists that captures the ridden component of the horse's life. To begin to address this gap, the Five Domains Model and existing welfare tools were leveraged to develop a ridden horse welfare survey. The survey was used to investigate the relationships between ridden horse behaviour, horse welfare and rider safety. It was hypothesised that horses with better relative welfare scores would perform fewer hyperreactive behaviours and have riders that reported fewer accidents and injuries. It was further hypothesised that less hyperreactive ridden behaviour would be related to fewer rider accidents and injuries.

2. Materials and methods

2.1. Survey recruitment and sample

Respondents were a convenience sample of Australian horse riders aged $\geq$ 18 years, reporting on (predominantly) their own sport/recreational horse. Recruitment was via Facebook for approximately 12 weeks, with strategies in place to maximise the representativeness of the sample. These included distributing the survey to a range of discipline-based interest groups (campdrafting, dressage, endurance, reining, showing, and trail riding) and equestrian organisations (Equestrian Australia and Pony Club Australia). An a priori power calculation using GPower (Faul et al., 2009), with a small effect size, $\alpha = 0.05$, Power = 0.80 determined a minimum sample size of 350 was required.

2.2. The survey

The survey was an online, self-report survey comprising 71 closed questions asking Australian riders how they care for (6 questions) and train (8 questions) their horses. Participants were asked to report on the behaviour of one horse they rode regularly, with questions about their horse's behaviour (27 questions), their estimated number of accidents and injuries (10 questions) and their satisfaction with their horse (10 questions). Remaining questions related to rider demographics (10 questions). The final question was an optional free text question which invited participants to share any additional information they deemed relevant to the survey. To aid accurate recall, participants were asked to report on their horse's behaviour in the previous seven days. This paper reports on the horse behaviour, horse welfare and rider accidents and injuries components of the survey.

2.3. Assessing ridden horse welfare

Welfare assessment has typically considered husbandry practices as the greatest psychological stressor (McBride and Mills, 2012), however, for a horse that is ridden, stress caused by riding, such as exposure to novel stimuli and environments, separation from conspecifics and exposure to unfamiliar horses (Borstel et al., 2017) and pain due to injury, poor training practices, ill-fitting tack, unbalanced and/or heavy riders, are likely equally important (McLean and Christensen, 2017). This understanding of ridden horse welfare is consistent with the recently updated Five Domains framework (Mellor et al., 2020). However, a validated measure of ridden horse welfare that assesses the ridden component of the horse's life does not exist. To operationalise this expanded view of ridden horse welfare, an online survey that captured horse husbandry practices and horse behaviour was developed. That withstanding, this study makes no claim that this tool provides an absolute measure of horse welfare, more rigorous studies are needed to achieve this goal. The online survey, however, did allow for the relative welfare of the sample horses to be ranked, which was sufficient for the purposes of this study. In keeping with the Five Domains Model which sees animal welfare as a complex, dynamic process (Mellor et al., 2020), horse welfare was considered from a systems thinking standpoint, with all aspects of a ridden horse's life considered an irreducible horse-human system (Luke et al., 2022, see Fig. 4 for an illustration of the horse-human system). Unlike Newtonian linear approaches to science, systems thinking conceptualises the world as a non-linear, dynamic (non-steady state), system that cannot be broken into its constituent parts (for a detailed description and discussion of a systems thinking approach to horse welfare see Luke et al. (2022)). This is not to suggest that traditional reductionist science has no role to play. The oscillation from holism (a systems view of the world) to mechanism (seeing the world as a linear, steady state machine) has been occurring since the times of the ancient philosophers (Capra and Luisi, 2014). However, like many dichotomies in science, it is likely neither approach is 'right' or 'wrong' but one approach can augment the other to arrive at more complete solutions to complex problems (Greenhalgh and Papoutsi, 2018). Therefore, in an attempt to capture some of the complexity of the horse-human system, horse welfare was measured using the following indicators: housing; feeding; transportation and competition; health problems (laminitis, ulcers, lameness, back problems); aggression towards and/or avoidance of humans; cooperation during hoof care, rushing in trot or canter when ridden and hyperreactive behaviour when ridden. These variables have been reported in the literature as either contributing to welfare or indicative of welfare status and were selected as they are objective and relatively easy for riders to self-assess (see Table 1).

Five-point Likert scale questions were used, with responses indicating better welfare receiving high scores and responses indicating poorer welfare receiving low scores (several items were reverse scored to reduce response bias). Raw scores for each variable were combined to

Table 1
Management practices, medical conditions and behavioural signals used to assess ridden horse welfare (in alphabetical order).

Management factors	Medical conditions	Signals during handling	Signals during riding
Competition (Jones & McGreevy, 2010; Borstel et al., 2017)	Back soreness (Buckley et al., 2013)	Aggression (AWIN, 2015; Fureix et al., 2010)	Bolting (Dyson et al., 2018a; McLean and Christensen, 2017)
Feeding (Lesimple, 2020)	Lameness (AWIN, 2015; Lesimple, 2020)	Apathy (AWIN, 2015; Fureix et al., 2010)	Bucking (Dyson et al., 2018a; McLean and Christensen, 2017)
Housing	Laminitis	Avoiding humans	Difficulty stopping
(Lesimple, 2020)	(Buckley, 2009; Lesimple, 2020)	(AWIN, 2015)	(Dyson et al., 2018a)
Transportation	Ulcers	Hoof handling	Ears back during transitions
(Jones & McGreevy, 2010;Padalino et al., 2018)	(Lesimple, 2020)	(Mansmann et al., 2011)	(Dyson et al., 2018a; Fureix et al., 2010)
		Stereotypy (AWIN, 2015; Lesimple, 2020)	Rearing (Dyson et al., 2018a; McLean and Christensen, 2017)
		Undesirable behaviour (handling) (AWIN, 2015)	Rushing (Dyson et al., 2018a)
			Saddle slip (Greve & Dyson, 2014;Borstel et al., 2017)
			Spooking (Dyson et al., 2018a; McLean and Christensen, 2017)
			Undesirable behaviour (ridden) (Hockenhull and Creighton, 2013)

Undesirable behaviour (ridden) was defined using the criteria from Hockenhull and Creighton (2013) as behaviours including: move off before asked when rider mounts, pull/lean on the bit, jog when asked to walk, resist slowing, spook.down when asked, trip or stumble, canter onthe wrong leg, rush over jumps, buck or pigroot, resist turning when asked, refuse to move forward when asked, stop at jumps, run out when jumping, rear, bolt.

create a relative horse welfare score (RWS) for each horse. The range of possible RWS scores was 0–84, with 0 indicating poorer welfare and 84 indicating higher welfare.

2.4. Assessing rider accidents and injuries

Falling from the horse is the most common cause of rider injury (Ball et al., 2007; Hawson et al., 2010; O'Connor et al., 2018), therefore, riders were asked to report on falls and near-miss falls while riding in the previous 12 months. Riders also reported their riding injuries in the last seven days (to maximise measure sensitivity) and their estimated number of injuries in the last 12 months to capture less frequent, but potentially more serious injuries. Accident and injury data were scored as continuous variables, with the seven day and 12-month scores combined to create a composite accident and injury score for each rider.

2.5. Data analysis

The relative horse welfare score (RWS) and rider accident and injury score were non-normally distributed continuous variables, so non-parametric tests were used to analyse the data. Variable-level comparisons were made using Spearman rank correlations and group comparisons used Kruskal-Wallis H tests. Hypotheses were one-directional, so one-tailed tests were used. The significance level was $p < 0.05$. Approximately 13 records (3%) had missing data, typically this was for questions towards the end of the survey. Missing data that contributed to the RWS was imputed using the median score for the variable. No imputation was undertaken for other variables. SPSS (IBM) version 26 for Windows (IBM Corporation, 2019) was used for all analyses.

3. Results

3.1. Horse and rider demographics

There were 427 completed surveys, respondents were mostly female (94.4%), aged 44.3 years (SD 13.9). Riders of all competency levels participated: 2.8% beginner (less than 60 h of lessons and/or other riding and/or still working on balance at canter), 7% novice (over 60 h of lessons and/or other riding and/or feel balanced at canter), 48.9% intermediate (over 200 h of lessons and/or other riding and have ridden several different horses), 37.9% advanced (competing/training at an advanced level and/or extensive experience training green/inexperienced horses), and 3.3% professional rider. Eighty-one per cent of all respondents belonged to an equestrian organisation. Equestrian organisations included Equestrian Australia, Pony Club Australia, Horse Riding Clubs Association of Victoria, Mounted Games Association, Sport Horse Racing Australia, Polocrosse Association of Australia, Australian Trail Horse Riders Association, plus various discipline-specific clubs (for example, working equitation, campdrafting, trail riding, endurance riding and show jumping) and breed societies (for example, Australian Quarter Horse Association, Australian Stock Horse Association). Mean horse age was 11.5 years (SD 4.9), with thoroughbreds (24.6%), warmbloods (18.3%) and Australian stock horses (9.8%) the most common breeds (Table 2).

3.2. Horse welfare: the relative welfare score

Respondents scored their horse for each of the variables in Table 1, these scores were added together to create a relative horse welfare score (RWS). Based on the welfare signals included in the survey, a hypothetical horse with good welfare (that is, a horse with a high RWS) would live in a paddock with one or more conspecifics; would not have a sore back, lameness, ulcers or stereotypies; would be caught easily; would not show aggression towards humans nor signs of depression or apathy; and would not exhibit hyperreactive behaviour under saddle. The median RWS was 71.0 (IQR 10.0).

3.3. Horse behaviour and horse welfare

The majority of horses (59%) performed one or more hyperreactive behaviours in the seven days prior to the survey. Of these, 50.8% spooked, 22.5% bucked, 4.0% bolted and 4.0% reared. Relative horse welfare score and ridden hyperreactive behaviour were significantly negatively related ($r = -0.55$, $p < 0.001$), as horse welfare score increased, the frequency of horse hyperreactive behaviour decreased (Fig. 1). Horse age was weakly related to ridden hyperreactive behaviour ($r = -0.21$, $p < 0.001$), with older horses performing fewer hyperreactive behaviours. Similarly, horse age and relative welfare score were

Table 2
Details of horse and rider demographics, rider's preferred discipline and equestrian organisation membership.

Demographic	N (%)	Mean (SD)
Rider age (years)	–	44.3 (13.9)
Female	403 (94.4)	
Male	24 (5.6)	
Own horse	367 (85.9)	
Length of partnership with the horse		
Less than 6 months	29 (6.8)	
6–12 months	41 (9.6)	
1–2 years	70 (16.5)	
3–4 years	85 (20.0)	
5–6 years	56 (13.2)	
More than 6 years	144 (33.9)	
Member of equestrian organisation	347 (81.3)	
Rider competency (self-report)		
Beginner	12 (2.8)	
Novice	30 (7.0)	
Intermediate	209 (48.9)	
Advanced	162 (37.9)	
Professional	14 (3.3)	
Discipline		
Dressage	140 (32.9)	
Trail riding	118 (27.7)	
Eventing	48 (11.2)	
Show jumping	24 (5.6)	
Endurance	16 (3.8)	
Western	14 (3.0)	
Show horse	12 (2.8)	
Camp drafting/team penning	7 (1.6)	
Polocrosse/Mounted Games	7 (1.6)	
Working equitation	6 (1.4)	
Breaking/starting/retraining	5 (1.2)	
Other	30 (7.0)	
Horse age (years)	–	11.5 (4.9)
Horse breed		
Thoroughbred	105 (24.6)	
Warmblood	83 (19.4)	
Australian Stock Horse	45 (10.5)	
Quarter Horse	43 (10.1)	
Arabian and arabian cross	30 (7.0)	
Clydesdale/Percheron/Heavy horse and heavy horse crosses	25 (5.9)	
Thoroughbred crosses/Warmblood crosses	22 (5.2)	
Standardbreds	17 (4.0)	
Cobs and cob crosses	13 (2.6)	
Pony breeds	12 (2.8)	
Welsh	11 (2.6)	
Connemara	5 (1.2)	
Brumby	4 (0.9)	
Other[a]	12 (2.8)	

Other included: Mixture of listed disciplines (majority), Pony Club, trick riding, vaulting, mustering, stock horse challenge, team sorting, team penning, hunting.
[a] Other included: Cross breed, American Saddlebred, Unknown, Mixed, and Tenessee Walking Horse

related ($r = 0.23$, $p < 0.001$), with older horses having slightly better welfare.

3.4. Rider accidents and injuries

In the previous 12 months, 41% (175) of riders reported a fall, 57% (244) reported a near-miss fall, with 67% (281) of riders reporting at least one fall or near miss. In the same period, 42% (180) reported an injury while 13% (57) reported an injury in the last seven days. Most falls were due to horse behaviour (75%), with only 19% of riders reporting falls due to losing balance, equipment failure or another external cause (6%). Of falls caused by horse behaviour, 84% were due to hyperreactive behaviour. Of the 16% of accidents caused by horse behaviour that was not deemed hyperreactive behaviour, most were due to horse trips or falls, followed by awkward striding to a jump and/or awkward jump over a fence.

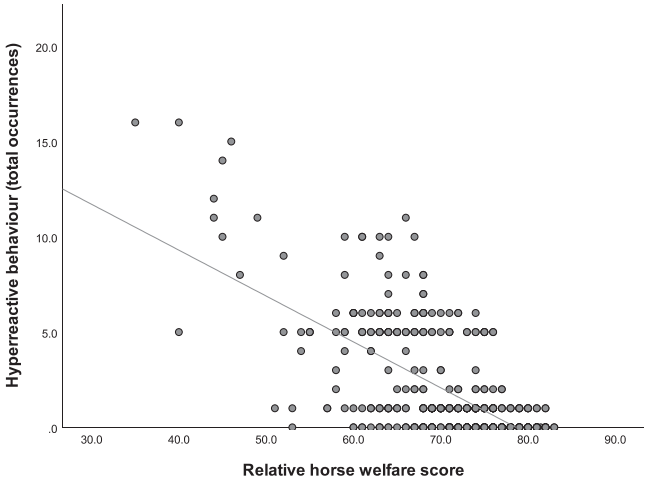


Fig. 1. Ridden hyperreactive behaviour was significantly negatively correlated (Spearman rank correlation) with horse welfare ($p < 0.001$).

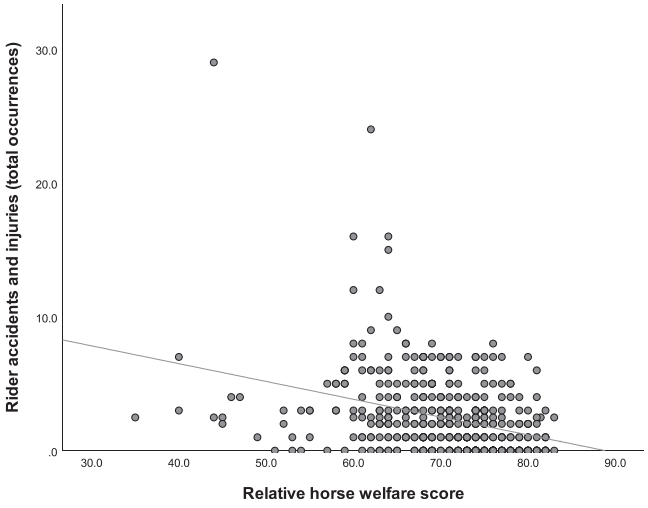


Fig. 2. Rider accidents and injuries were significantly negatively correlated (Spearman rank correlation) with relative horse welfare score ($p < 0.001$).

3.5. Horse behaviour, horse welfare and rider safety

A significant negative relationship was found between relative horse welfare score and rider accidents and injuries ($r = -0.37$, $p < 0.001$, Spearman rank correlation, Fig. 2). Ridden hyperreactive behaviour was significantly and positively correlated with rider accidents and injuries ($r = 0.34$, $p < 0.001$, Spearman rank correlation). However, horse age was not related to accidents and injuries ($p > 0.05$).

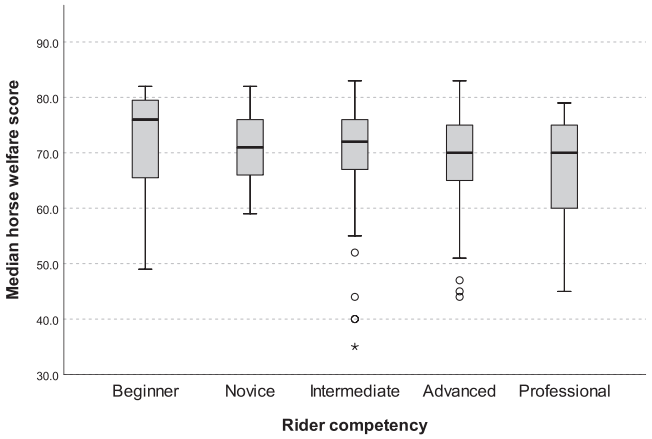


Fig. 3. No relationship was found between relative horse welfare score and rider competency level using a ($p > 0.05$, n = 427, Kruskal Wallis H test). (Note: circles and asterisks identify outliers in the sample). Rider competency levels were defined as follows: Beginner: Less than 60 h of lessons and/or other riding and/or still working on balance at canter; Novice: Over 60 h of lessons and/or other riding and/or feel balanced at canter; Intermediate:Over 200 h of lessons and/or other riding and have ridden several different horses, Advanced: Riders competing/training at an advanced level and/or extensive experience training green/inexperienced horses; Professional: Riders who ride professionally as a career.

3.6. Rider competency, rider safety and horse welfare

Horse welfare score did not differ across rider competency levels (Kruskal Wallis H test, $p > 0.09$, Fig. 3). Consistent with this finding, rider accidents and injuries also did not differ across rider competency levels (Kruskal Wallis H test, $p > 0.09$).

4. Discussion

Horse behaviour and horse welfare are related to rider safety. Riders reported horse behaviour to be the cause of the majority of falls and the majority of horses performed one or more hyperreactive behaviours in the week before the survey. Most participants reported at least one accident, near-miss or injury in the previous 12 months, confirming the dangers of horse riding (Kreisfeld and Harrison, 2020; Pounder, 1984). Horse welfare was unrelated to rider competency level. Surprisingly, numbers of horse-related accidents and injuries were the same for riders of all competency levels. These results raise many questions surrounding horse care and training practices, the measurement of ridden horse welfare and horse-related safety initiatives.

This is perhaps the first study to show a relationship between horse welfare, horse behaviour and rider accidents and injuries. The poor welfare outcomes of many routine horse care and training practices have been raised by equitation scientists for several decades (for example, McLean, 2013; Ödberg and Bouissou, 1999). One signal of poor welfare in ridden horses is hyperreactive behaviour (McLean and Christensen, 2017). Our finding that almost 60% of horses performed one or more hyperreactive behaviours in the week prior to the survey supports their concerns and suggests a serious welfare problem may exist among Australian riding horses. Moreover, finding that horse welfare, horse behaviour and human safety are interrelated, combined with the high frequency of hyperreactive behaviour reported in this study, might explain (to some extent) the poor safety record of the Australian horse industry (Gordon, 2001).

The high levels of hyperreactivity found in this study raise the questions of why is it so prevalent and what can be done to reduce it? Hyperreactivity occurs when a horse is exposed to intolerable aversive stimuli (pain) (McLean and Christensen, 2017) or stress (Borstel et al., 2017) and is an attempt to relieve that pain or stress. When ridden, the horse can experience pain from injuries (Dyson et al., 2018; Lesimple et al., 2016), harsh bits or harsh use of bits (Mellor, 2020), concurrent and excessive use of conflicting equipment such as spurs and harsh bits (Condon et al., 2021), ill-fitting tack and/or an unbalanced or heavy rider (Borstel et al., 2017), as well as poorly timed, excessive or inappropriate use of negative reinforcement or punishment (McLean and Christensen, 2017). Furthermore, ridden horses are regularly exposed to stress-inducing novel stimuli, situations or environments inducing neophobia (for example when horses are taken out to competitions, attend lessons or equestrian club activities), separation from conspecifics and/or proximity to unfamiliar horses and transportation (Borstel et al., 2017). An owner has direct control over the use of conflicting, harsh or ill-fitting equipment, their level of knowledge and skill in selecting and applying training practices and the frequency with which horses are exposed to stressful situations. Therefore, recognition, minimisation and/or remediation of these factors represents an opportunity for owners to improve not only their horse's welfare but their own safety.

Rider competence was unrelated to accidents and injuries and, somewhat surprisingly, horse welfare. Finding no relationship between rider competence and safety is consistent with previous research (Ball et al., 2007; O'Connor et al., 2018). However, the lack of benefit to horses of having a competent rider suggests the known shortcomings of many horse care and training practices are either unrecognised or ignored by competent riders, something others have highlighted (Bergmann, 2020; McLean, 2013; Mellor, 2020). Advanced and professional riders often teach less competent riders either independently or through equestrian organisations. Therefore, an opportunity exists for equestrian organisations to adopt a leadership position by revisiting their rules and training programs to ensure practices related to poor horse welfare are replaced with practices that deliver good horse welfare. For example, practices such as over-tightened nosebands (Fenner et al., 2016; Uldahl and Clayton, 2019) and riding horses with their head behind the vertical (Borstel et al., 2017; McLean and Christensen, 2017; Zebisch et al., 2014) are known to cause pain and stress to horses. Research has shown that these practices can be significantly reduced by equestrian organisations changing and enforcing their rules (Doherty et al., 2017; Luke et al., 2021; Visser et al., 2019). Initiatives by equestrian organisations to exclude practices that lead to poor horse welfare (as evidenced by hyperreactive behaviours) may not only improve rider safety but may well produce additional industry benefits such as reduced insurance costs to members (which are often substantial) (Meggitt, 2017) and improved community acceptability (ISES, 2021).

Recognising that behaviours indicative of reduced horse welfare are related to human safety creates numerous opportunities to improve both. Traditional horse-related safety approaches have focused primarily on technological innovations such as improved helmets and body-protecting vests (Thompson et al., 2015). Innovations in personal protective equipment no doubt play an important role in improving horse-related safety, however, they afford the lowest level of protection according to the hierarchy of control (Safe Work Australia, 2021). These findings create opportunities at the higher level of protection, which is risk reduction (Safe Work Australia, 2021). The diverse range of indicators used to assess ridden horse welfare in this study (Table 1) reflects the complex nature of ridden horse-human interactions. One conceptualisation attempting to highlight this complexity, and the dynamic nature of welfare emphasised in the Five Domains Model (Mellor et al., 2020), is the horse-human system depicted in Fig. 4 (for a detailed discussion of the systems thinking approach to horse welfare underpinning Fig. 4, see Luke et al., 2022). The horse-human system contends that changes in horse care or training resulting in improved welfare will be reflected in positive horse behaviour (calm, cooperative, predictable), which in turn offers human safety gains. Conversely, changes in care and training that reduce horse welfare will result in negative horse behaviour (hyperreactive, aggressive, unpredictable) and increase human risk. Each iteration of this cycle, that is, each time a person

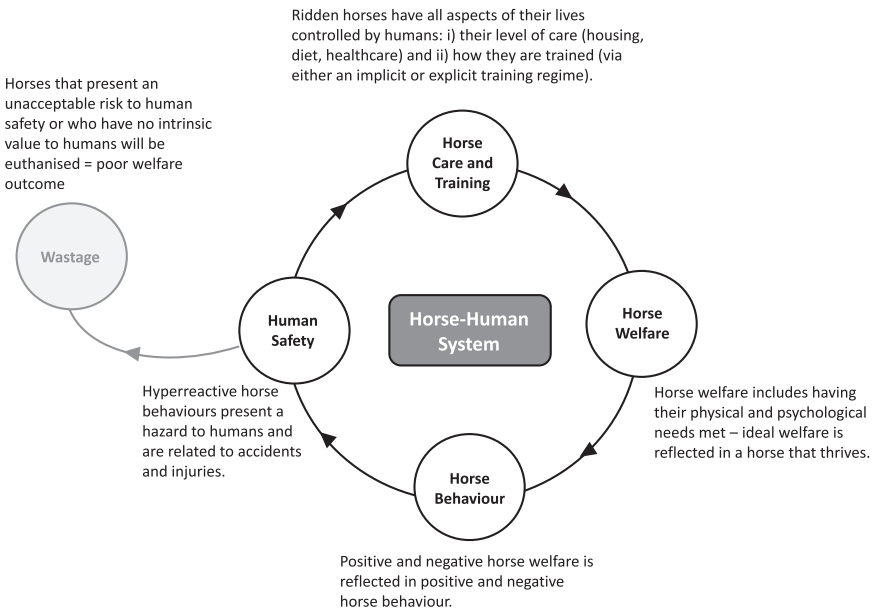


Fig. 4. The Horse-Human System. A simplified schematic illustrating the pivotal role of horse care and training practices in determining horse welfare and human safety. Each node represents a broad construct within the system, beneath which are innumerable elements and interconnections (for more detail see Luke et al., 2022).

interacts with their horse, presents an opportunity to improve or diminish their horse's welfare and thus their own safety. When combined with traditional safety approaches, the findings of this research have the potential to deliver meaningful safety gains in an industry where solutions to this problem have been elusive.

While providing evidence of a relationship between horse behaviour, horse welfare and human safety, this study was not without limitation. Data were self-reported from a convenience sample. Despite this, the horse and rider demographics were broadly consistent with other similar online studies (Hockenhull and Creighton, 2013; Ikinger et al., 2016; Merkies et al., 2018). Self-report data may be biased in terms of social desirability; however, the anonymity of online surveys can minimise this distortion (Fricker and Schonlau, 2002). Another concern is the retrospective nature of the accident and injury data, where balancing the accuracy of recall and sensitivity of the measure is challenging (Stull et al., 2009). This study attempted to optimise this balance by asking participants to report injuries over the previous 12 months, and, to increase sensitivity, also report injuries over the previous seven days. Horse-human interactions are complex, and a retrospective, self-report survey might not be a particularly sensitive or sophisticated measure, however care was taken to select welfare indicators and behaviours easily identified and quantified by a lay owner (AWIN, 2015; AWIN Italy, 2021). Notwithstanding these limitations, our results consistently supported our hypotheses using an appropriately sized sample, suggesting that horse behaviour and horse welfare are indeed related to human safety and that this is an area worthy of more rigorous investigation. Furthermore, the self-report nature of this study demonstrates it is possible to develop tools for riders that are accessible and sensitive enough to detect changes in horse welfare status that may warn of danger in the saddle.

The notion that horse behaviour and horse welfare are related to human safety intuitively makes sense and has been proposed by scholars over several decades (Ödberg and Bouissou, 1999; Warren-Smith and McGreevy, 2008). While recognising that horses are large and accidents happen, this study challenges the belief that horse-riding must be dangerous, and riders must accept getting hurt (Thompson et al., 2015). Instead, it offers a new approach that invites riders, owners and equestrian organisations to re-think common horse care and training practices that result in poor horse welfare. Not only do these practices harm horses, but we now know they harm riders. Hyperreactive behaviour, a signal of poor welfare, is related to (among other things), poor training methods, indicating research investigating not only riders' knowledge of learning theory but also its application, is warranted. Having shown that it is possible for riders to self-assess their horse's welfare, equipping riders with a tool to assess their horse's welfare status could begin to raise their awareness of the welfare impacts (positive and negative) of their horse care and training practices. Additionally, the development of tools that allow riders to accurately interpret their horse's behaviour may begin to address one of the most significant welfare issues facing horses, which is the misinterpretation of pain and/or stress behaviour (Horseman, 2017). The flow-on effects of the increased salience of their horse's welfare and accurate interpretation of their horse's behaviour, coupled with recognising that horse welfare and their own safety are connected, may encourage the adoption of practices that enhance the welfare of horses and likewise, their riders.

Source of funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

CRediT authorship contribution statement

Karen Luke: Conception and design of the study; Acquisition, Analysis and interpretation of data, Drafting the article. Tina McAdie Bradley Smith and Amanda Warren-Smith: Analysis and interpretation of data, Critical review for intellectual content and editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

Data are available on request from the authors.

Acknowledgements

The authors would like to thank the anonymous peer reviewers for their helpful feedback on an earlier version of this manuscript and members of the Australian horse community who generously contributed their time to complete the detailed survey.

Ethical animal research

No animals were used in this research.

Informed consent

This project received human ethics clearance from Central Queensland University Human Ethics Committee (ethics approval number 0000022790) and all participants provided electronic informed consent before completing the survey.

References

Abu-Kishk, I., Klin, B., Gilady-Doron, N., Jeroukhimov, I., Eshel, G., 2013. Hospitalization due to horse-related injuries: has anything changed? a 25 year survey. Isr. Med. Assoc. J. 15, 235–238. ⟨https://www.ima.org.il/MedicineIMAJ/viewarticle.aspx?aid=2214⟩.

Abu-Zidan, F.M., Rao, S., 2003. Factors affecting the severity of horse-related injuries. Injury 34 (12), 897–900. https://doi.org/10.1016/s0020-1383(03)00054-8.

Acton, A.S., Gaw, C.E., Chounthirath, T., Smith, G.A., 2020. Nonfatal horse-related injuries treated in emergency departments in the United States, 1990-2017. Am. J. Emerg. Med. 38 (6), 1062–1068. https://doi.org/10.1016/j.ajem.2019.158366.

AWIN, 2015 , AWIN welfare assessment protocol for horses. https://doi.org/10.13130/AWIN_HORSES_2015.

AWIN Italy, 2021 , AWINHorse. ⟨https://play.google.com/store/apps/details?id=com.daia.awinhorse&hl=en_US&gl=US⟩.

Ball, C.G., Ball, J.E., Kirkpatrick, A.W., Mulloy, R.H., 2007. Equestrian injuries: incidence, injury patterns, and risk factors for 10 years of major traumatic injuries. Am. J. Surg. 193 (5), 636–640. https://doi.org/10.1016/j.amjsurg.2007.01.016.

Barber, H.M., 1973. Horse-play: survey of accidents with horses. Br. Med. J. 3 (5879), 532–534. https://doi.org/10.1136/bmj.3.5879.532.

Bergmann, I., 2020. Naturalness and the legitimacy of Thoroughbred racing: a photo-elicitation study with industry and animal advocacy informants. Animals 10 (9), 1513. https://doi.org/10.3390/ani10091513.

Borstel, K.önig v, Visser, U., Hall, C, E.K., 2017. Indicators of stress in equitation. Appl. Anim. Behav. Sci. 190, 43–56. https://doi.org/10.1016/j.applanim.2017.02.018.

Buckley, P., 2009. Epidemiological studies of health and performance in Pony Club horses. PhD Thesis, The University of Queensland.

Buckley, P., Morton, J., Buckley, D., Coleman, G., 2013. Misbehaviour in Pony Club horses: incidence and risk factors. Equine Veterinary Journal 45 (1), 9–14. https://doi.org/10.1111/j.2042-3306.2011.00541.x.

Capra, F., Luisi, P.L., 2014. The Systems View of Life: A Unifying Vision. Cambridge University Press. https://doi.org/10.1017/CBO9780511895555.

Chitnavis, J.P., Gibbons, C.L., Hirigoyen, M., Lloyd Parry, J., Simpson, A.H., 1996. Accidents with horses: what has changed in 20 years? Injury 27 (2), 103–105. https://doi.org/10.1016/0020-1383(95)00176-x.

Condon, V.M., McGreevy, P.D., McLean, A.N., Williams, J.M., Randle, H., 2021. Associations between commonly used apparatus and conflict behaviours reported in the ridden horse in Australia. J. Vet. Behav. https://doi.org/10.1016/j.jveb.2021.10.014.

Dekker, R., van Der Sluis, C., Kootstra, J., Groothoff, J.W., Eisma, W., Ten Duis, H., 2004. Long-term outcome of equestrian injuries in children. Disabil. Rehabilit. 26 (2), 91–96. https://doi.org/10.1080/09638280310001629688.

Doherty, O., Casey, V., McGreevy, P., Arkins, S., 2017. Noseband use in equestrian sports – an international study. PLoS One 12 (1), e0169060. https://doi.org/10.1371/journal.pone.0169060.

Dyson, S., Berger, J.M., Ellis, A.D., Mullard, J., 2018. Behavioral observations and comparisons of nonlame horses and lame horses before and after resolution of lameness by diagnostic analgesia. J. Vet. Behav. 26, 64–70. https://doi.org/10.1016/j.jveb.2018.05.001.

Faul, F., Erdfelder, E., Buchner, A., Lang, A.G., 2009. Statistical power analyses using G*Power 3.1: tests for correlation and regression analyses. Behav. Res. Methods 41 (4), 1149–1160. https://doi.org/10.3758/BRM.41.4.1149.

Fenner, K., Yoon, S., White, P., Starling, M., McGreevy, P., 2016. The effect of noseband tightening on horses' behavior, eye temperature, and cardiac responses. PLoS One 11 (5), e0154179. https://doi.org/10.1371/journal.pone.0154179.

Fraser, D., 2009. Assessing animal welfare: different philosophies, different scientific approaches. Zoo Biol. 28 (6), 507–518. https://doi.org/10.1002/zoo.20253.

Fricker, R.D., Schonlau, M., 2002. Advantages and disadvantages of internet research surveys: evidence from the literature. Field Methods 14 (4), 347–367. https://doi.org/10.1177/152582202237725.

Fureix, C., Menguy, H., Hausberger, M., 2010. Partners with bad temper: reject or cure? A study of chronic pain and aggression in horses. PloS One 5 (8). https://doi.org/10.1371/journal.pone.0012434.

Gordon, J., 2001. The Horse Industry: Contributing to The Australian Economy. Rural Industries Research and Development Corporation. Barton, pp. 1–66. ⟨https://www.agrifutures.com.au/product/the-horse-industry-contributing-to-the-australian-economy/⟩.

Greenhalgh, T., Papoutsi, C., 2018. Studying complexity in health services research: desperately seeking an overdue paradigm shift. BMC Med. 16 (1) https://doi.org/10.1186/s12916-018-1089-4.

Greve, L., Dyson, S., 2014. The interrelationship of lameness, saddle slip and back shape in the general sports horse population. Equine Veterinary Journal 46 (6), 687–694. https://doi.org/10.1111/evj.12222.

Hall, C., Huws, N., White, C., Taylor, E., Owen, H., McGreevy, P., 2013. Assessment of ridden horse behavior. J. Vet. Behav. 8 (2), 62–73. https://doi.org/10.1016/j.jveb.2012.05.005.

Hawson, L.A., McLean, A.N., McGreevy, P.D., 2010. The roles of equine ethology and applied learning theory in horse-related human injuries. J. Vet. Behav. 5 (6), 324–338. https://doi.org/10.1016/j.jveb.2010.06.001.

Hockenhull, J., Creighton, E., 2013. The use of equipment and training practices and the prevalence of owner-reported ridden behaviour problems in UK leisure horses. Equine Vet. J. 45 (1), 15–19. https://doi.org/10.1111/j.2042-3306.2012.00567.x.

Horseman, S., 2017. The four priority welfare challenges. Equine Vet. Educ. 29 (8), 415–416. https://doi.org/10.1111/eve.12729.

IBM Corporation, 2019 , IBM SPSS Statistics for Windows. In (Version 26.0) IBM Corp.

Ikinger, C.-M., Baldamus, J., Spiller, A., 2016. Factors influencing the safety behavior of German equestrians: attitudes towards protective equipment and peer behaviors. Animals 6 (2), 14. https://doi.org/10.3390/ani6020014.

(ISES), I. S. o. E. S, 2021, Newsletter. ⟨https://equitationscience.com/media/january-international-society-of-equation-science-newsletter⟩.

Jones, B., McGreevy, P., 2010. Ethical equitation: Applying a cost-benefit approach. Journal of Veterinary Behavior 5 (4), 196–202. https://doi.org/10.1016/j.jveb.2010.04.001.

Kreisfeld, R., Harrison, J.E., 2020. Hospitalised sports injury in Australia, 2016-17. Aust. Inst. Health Welf. 1–20. INJCAT 131.

Kruger, L., Hohberg, M., Lehmann, W., Dresing, K., 2018. Assessing the risk for major injuries in equestrian sports. BMJ Open Sport Exerc. Med. 4 (1), 1–9. https://doi.org/10.1136/bmjsem-2018-000408.

Lesimple, C., 2020. Indicators of horse welfare: state-of-the-art. Animals 10 (2). https://doi.org/10.3390/ani10020294.

Lesimple, C., Fureix, C., Aube, L., Hausberger, M., 2016. Detecting and measuring back disorders in nonverbal individuals: the example of domestic horses. Anim. Behav. Cogn. 3 (3), 159–179. https://doi.org/10.12966/abc.05.08.2016.

Luke, K. , Rawluk, A. , McAdie, T. , A key opportunity for improving horse welfare: the importance of rules in equestrian sport ISAE2021 54th Congress of International Society for Applied Ethol. Online 2021.⟨https://www.applied-ethology.org/ISAE_Meetings.html⟩.

Luke, K., Rawluk, A., McAdie, T., 2022. A new approach to horse welfare based on systems thinking. Anim. Welf. 31, 37–49. https://doi.org/10.7120/09627286.31.1.004.

Mansmann, R., Currie, M., Correa, M., Sherman, B., vom Orde, K., 2011. Equine Behavior Problems—Around Farriery: Foot Pain in 11 Horses. Journal of Equine Veterinary Science 31 (1), 44–48. https://doi.org/10.1016/j.jevs.2010.11.018.

McBride, S.D., Mills, D.S., 2012. Psychological factors affecting equine performance. BMC Vet. Res. 8 (1), 180. https://doi.org/10.1186/1746-6148-8-180.

McGreevy, P. , McLean, A. , Warren-Smith, A.K. , Goodwin, D. , Waran, N. , Defining the terms and processes associated with equitation P. McGreevy A. McLean A.K. Warren-Smith D. Goodwin N. Waran Proceedings of the 1st International Equitation Science Symposium 2005 10 43.

McLean, A.N., 2013. Training the ridden animal: an ancient hall of mirrors. Vet. J. 196 (2), 133–136. https://doi.org/10.1016/j.tvjl.2012.10.031.

McLean, A.N., Christensen, J.W., 2017. The application of learning theory in horse training. Appl. Anim. Behav. Sci. 190, 18–27. https://doi.org/10.1016/j.applanim.2017.02.020.

Meggitt, J. , 2017. The average cost of equine liability insurance. Retrieved 16 December 21 from ⟨https://bizfluent.com/info-8745397-average-cost-equine-liability-insurance.html⟩.

Mellor, D.J., 2020. Mouth pain in horses: physiological foundations, behavioural indices, welfare implications, and a suggested solution. Animals 10 (4). https://doi.org/10.3390/ani10040572.

Mellor, D.J., Beausoleil, N.J., Littlewood, K., McLean, A., McGreevy, P., Jones, B., Wilkins, C., 2020. The 2020 five domains model: including human-animal interactions in assessments of animal welfare. Animals 10 (10), 1870. https://doi.org/10.3390/ani10101870.

Meredith, L., Ekman, R., Brolin, K., 2018. Epidemiology of equestrian accidents: a literature review. Internet J. Allied Health Sci. Pract. 17 (1), Article 9. ⟨https://nsuworks.nova.edu/ijahsp/vol17/iss1/9/⟩.

Meredith, L., Brolin, K., Ekman, R., Thomson, R., 2019. Analyses of injuries to equestrians in a Swedish district over a 16–year period. Transl. Sports Med. 2 (5), 270–278. https://doi.org/10.1002/tsm2.94.

Merkies, K., Nakonechny, L., DuBois, C., Derisoud, E., 2018. Preliminary study on current perceptions and usage of training equipment by horse enthusiasts in Canada. J. Appl. Anim. Welf. Sci. 21 (2), 141–152. https://doi.org/10.1080/10888705.2017.1392301.

National Coronial Information System, 2020. Animal-related deaths in Australia. NCIS Fact. Sheet 1–3. ⟨https://www.ncis.org.au/publications/ncis-fact-sheets/animal-related-deaths-2/⟩.

O'Connor, S., Hitchens, P.L., Fortington, L.V., 2018. Hospital-treated injuries from horse riding in Victoria, Australia: time to refocus on injury prevention? BMJ Open Sport Exerc. Med. 4 (1) https://doi.org/10.1136/bmjsem-2017-000321.

Ödberg, F.O., Bouissou, M.F., 1999. The development of equestrianism from the baroque period to the present day and its consequences for the welfare of horses. Equine Vet. J. 28, 26–30. https://doi.org/10.1111/j.2042-3306.1999.tb05152.x.

Padalino, B., Raidal, S., Knight, P., Celi, P., Jeffcott, L., Muscatello, G., 2018. Behaviour during transportation predicts stress response and lower airway contamination in horses. PloS One 13 (3). https://doi.org/10.1371/journal.pone.0194272.

Pounder, D.J., 1984. "The grave yawns for the horseman." Equestrian deaths in South Australia 1973-1983. Med. J. Aust. 141 (10), 632–635. ⟨https://www.ncbi.nlm.nih.gov/pubmed/6493111⟩.

Safe Work Australia , Identify, assess and control hazards Retrieved 30 September 2021 2021.⟨https://www.safeworkaustralia.gov.au/risk#controlling-risks-using-the-hierarchy⟩.

Stull, D.E., Leidy, N.K., Parasuraman, B., Chassany, O., 2009. Optimal recall periods for patient-reported outcomes: challenges and potential solutions. Curr. Med. Res. Opin. 25 (4), 929–942. https://doi.org/10.1185/03007990902774765.

Thompson, K., McGreevy, P., McManus, P., 2015. A critical review of horse-related risk: a research agenda for safer mounts, riders and equestrian cultures. Animals 5 (3), 561–575. https://doi.org/10.3390/ani5030372.

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

Visser, E.K., Kuypers, M.M.F., Stam, J.S.M., Riedstra, B., 2019. Practice of noseband use and intentions towards behavioural change in Dutch equestrians. Animals 9 (12), 1131. https://doi.org/10.3390/ani9121131.

Warren-Smith, A.K., McGreevy, P.D., 2008. Equestrian coaches' understanding and application of learning theory in horse training. Anthrozoös 21 (2), 153–162. https://doi.org/10.2752/175303708x305800.

Zebisch, A., May, A., Reese, S., Gehlen, H., 2014. Effect of different head–neck positions on physical and psychological stress parameters in the ridden horse. J. Anim. Physiol. Anim. Nutr. 98 (5), 901–907. https://doi.org/10.1111/jpn.12155.