Journal of Veterinary Behavior (2010) 5, 324-338

ELSEVIER

Journal of Veterinary Behavior
Clinical Applications and Research

RESEARCH

The roles of equine ethology and applied learning theory in horse-related human injuries

Lesley A. Hawson[a], Andrew N. McLean[b], Paul D. McGreevy[a]

[a]*Faculty of Veterinary Science, University of Sydney, New South Wales, Australia; and*
[b]*Australian Equine Behavior Centre, Broadford, Victoria, Australia.*

KEYWORDS:
horse;
injury;
equitation;
training;
ethology

Abstract Horse-related injuries to riders, handlers, and veterinarians can be both serious and long-term in their effects on the victim. This review of literature covering horse-related injuries to human beings sought to identify rider and handler injury incidence and the relationships between antecedents and demographics of incidents. Review and evaluation of previously recommended prevention strategies were also undertaken.

There was evidence that recent technological advances in protective equipment may have mitigated some injuries but the frequency of the incident has not changed. Despite several authors acknowledging the important role the horse played in many of the incidents, there was little specific detail about this role recorded. The emerging field of equitation science will contribute important insights that make horse-use safer by reducing the "unpredictability" aspect of horse–human interactions.

Introduction

Despite millennia of horse domestication and training, horse-riding and handling is still acknowledged as a dangerous pastime (Nelson and Bixby-Hammett, 1992; Abu-Zidan and Rao, 2003; Lim et al., 2003; Jagodzinski and DeMuri, 2005; Seibenga et al., 2006; Ball et al., 2007; Mayberry et al., 2007; Kiss et al., 2008; Bilaniuk et al., 2009). Although injuries incurred in horse-related incidents can be very serious and even fatal, recreational equestrian activities continue to grow in popularity in many parts of the world. Recent advances in learning theory and ethology as applied to horses in the form of equitation science are likely to reduce the injury risk to people involved with horses, for example, by clarifying ethological challenges at the horse–human interface (McGreevy et al., 2009). Demystifying horse-training should make horse interactions with human beings more predictable. Although the mechanisms that underpin effective training are being more broadly accepted, there is also opportunity for exploration of the communication processes between the 2 species (Feh and de Mazières, 1993; McGreevy et al., 2004; Keeling et al., 2009; McGreevy et al., 2009). To this end, we reviewed the data published in English over the past 20 years to collate the data available on injuries to human beings in horse-related incidents. We sought to identify any consistent trends in the demographics of those injured, causes of injury, risk factors for injury, role of personal protective equipment, and recommendations by authors of the articles for prevention of injury. We were particularly interested in identifying horse-related causes for human injuries.

Address for reprint requests and correspondence: Lesley A. Hawson, Faculty of Veterinary Science, University of Sydney, NSW 2006, Australia.
E-mail: lhawson@gmail.com

1558-7878/$ - see front matter
doi:10.1016/j.jveb.2010.06.001

Materials and methods

A review of the articles cited was undertaken through the Web of Knowledge and Scopus databases using "horse-related injuries" and "equestrian injuries" as the search terms. We excluded articles that specifically covered the racing industry, as our aim was to target the sporting and leisure horse industry. We clustered data into the following 4 broad categories:

- Adult and child riders and non-riders (19 articles)
- Adult-only riders and non-riders (4 articles)
- Child-only riders and non-riders (3 articles)
- Veterinarians (2 articles)

Non-riders included horse handlers and bystanders. Veterinarians were included as a specific occupational group to compare whether handling injuries differed from handling injuries to owners. Because all articles reviewed used different measures for evaluating incident rates and injury severity, we tried to express as many of the variables as was possible as simple percentages. We also reviewed Australian Government statistics on horse-riding demographics using reports 4177.0 and 4901.0 downloaded from the Australian Bureau of Statistics website.

Results

Demographics of horse-riders

In its analysis of participation in sports, the Australian Bureau of Statistics (ABS, 2007) defines people aged >15 years as adults. It reports that the most populous cohort participating in horse-riding among persons aged >15 years was in the age group 35 to 44 years (27%), followed by the 25 to 34 years age group (20.6%). The 45 to 54 years age group made up 19.1% of horse-riding participants and the 18 to 24 year age group made up 16.4%. The 15 to 17 and the 55 to 64 years age groups made up 9.7% and 7.1% of the horse-riding participants, respectively. There were no data available from this resource on the age distribution of children involved in equestrian activities. Females made up 80% of adult (aged >15 years) participants in equestrian activities (ABS, 2007) and 86.8% of equestrian participants aged <15 years (ABS, 2009).

Demographics of those injured

Studies of adults and child riders only (Table 1) reported a bimodal pattern to injury frequency, with most injuries occurring in the second and fifth decades of life (Loder, 2008). Females predominated in younger age groups but males were more highly represented in older age groups. Some authors reported that although fewer males appeared in younger age groups, they often presented with more severe injuries as compared with their female counterparts (Jagodzinski and DeMuri, 2005; Cuenca et al., 2009). In the non-veterinary adults-only studies (Table 2), average age was reported to be within the fourth and fifth decades. Bilaniuk et al. (2009) found that patients older than 50 years were more likely to sustain fractures of ribs and thoracolumbar vertebrae, whereas patients younger than 50 years were more likely to present with concussion and fractures of the upper extremities. Upper extremity injuries also figured prominently in studies of equestrian-related trauma in children, with contusions, abrasions, and fractures showing a broadly equal frequency.

Patients aged <35 years were represented in greater numbers as compared with other age groups (Tables 2 and 3). Females represented 20% and 26%, respectively, of those injured in the veterinary studies (Table 4). No age-related data were recorded in these 2 studies.

Causes of injuries

The most common mechanism of injury in the studies, except for the veterinary-specific studies, was falling and/or being thrown from the horse (range, 46%-83% of incidents). Injuries among non-riders were most often caused by kicks (range, 0.8%-41% for riders and handlers, 7%-82% handler and bystanders). Veterinarians reported that 79% of injuries were caused by kicks (Lucas et al., 2009). Bites did not figure highly as a cause of injury.

Risk factors for injury

Jagodzinski and De Mura (2005) found significant risk factors for horse-related accidents included being female, participating in English-style riding, and riding 15 to 24 hours per month. Kiss et al. (2008) found that children who owned horses (or whose families owned horses) were more likely to receive injuries during handling.

Most of the studies found that riding incidents typically occurred within 3 years of the rider's first horse-riding experience. Clarke et al. (2008) showed that novice riders (categorized as those with fewer than 100 hours riding experience) were more vulnerable to accidents than riders with greater experience. In an earlier study, Ingemarson et al. (1989) had found that young horses and horses whose height was >148 cm were associated with an elevated risk of injury. They also observed lower risk in trotting than the galloping gaits.

Williams and Ashby (1995) reported that horse-related accidents were more common in warmer than in the cooler months. Accidents most often occurred in a field or paddock. This study also found horse behavior to be the most significant factor in horse-related incidents and that the majority of case reports alluded to the horse showing a fear response. Ball et al. (2007) also reported some factors related directly to the horses involved in their data set. In

Table 1 Summary of articles that covered children and adults

Author(s) and year of publication (Country period of data collection)	Accident rate per 100,000 people	Female (%)	Most frequent injury	Most frequent site of injury	Severity (ISS[a] score)	Hospitalization-related statistics	Age group features (years)	Most common mechanism of injury	Context	Rider-related features	Horse-related features
Abu-Zidan and Rao, 2003 (prospective hospital records, Australia, 1994-2000)		**59**	**Fractures**	**Head and face 27%, neck 5%, chest 8%, abdomen 6%, pelvis 8%, back 13%, upper limb 32%, lower limb 30%**	**Mean 7.2**	**100% as cases selected by hospital admission. Those that had more than one mechanism of injury stayed longer**	**Mean age females: 31 Mean age males: 38**	**Falls 67%, kicks 16%, other 17%**	**Park or public place 55% of incidents**	**Amateurs: 66%**	
Bilaniuk et al., 2009 (New Jersey, 2004-2007)		84		>50 yrs, rib fractures 23%, T-L-S spine fractures 18% <50 yrs, concussion 22%, upper extremity fracture 16%							
Chitnavis et al., 1996 (UK, 1991)		**75**		**Head 6%, upper limbs 42%, lower limb 38%**		**24%**	**10-20 yrs, 26%; 20-30 yrs 23%**	***Riders* (78% of caseload): Falls 83%, crushed by horse falling 14%, struck obstacles 55%, entrapment in reins 5% *Bystander/ handler* (22% of caseload): kicked or stamped on 82%, bitten 10%, run into by horse 8%**		**Amateurs: 75% professional: 25%**	
Cripps, 2000 (Australia Bureau of Statistics mortality records 1979-1998)	0.13 deaths per 100,000 people (7.8 horse-related deaths per 100,000 participants)	15-24 yrs of age: 54% 35-54 yrs of age: 29%					15-24 yrs (54% female) and 35-54 yrs (71% males)				

Cripps, 2000 (hospital data Australia Institute of Health and Welfare 1996-1997)	17 estimated incident cases of horse-related injury per 100,000 people	5-34 yrs of age: 58%. From age of 35 on, males have a higher accident rate than females	Fracture, intracranial injury	Upper extremity, head		Average length of stay 3 days	10-14 yrs,	Falls or being thrown			
Exadaktylos et al., 2002 (Bern, Switzerland, 2000-2001)		**65**	**Fractures or deep lacerations**	**Face**[b]			**Mean age, female: 27 Mean age, male: 31**	**21% of the 80 equestrian accidents seen at the hospital were from direct hoof kick. All unmounted; standing next to or behind horse.**			
(Japan, 1985-1991)			**Bruises (38.7%), fractures (23.2%), abrasions and lacerations (21.4%)**	**Lower limb 23.7%, shoulder and upper limb 20.4%, chest 17.7%**	**565 patients 0-9, 16 patients 10 or greater**			**Kicks 39.2%, falls 18.1%, trampling 15.3%**		**Handlers only**	
Ingemarson et al., 1989 (Sweden, 1969-1982)		More females than males injured until 25 years of age, then females and males same rate of injury until after 46 years of age when males have higher injury rate	Fracture of skull with cerebral contusion or laceration	Head 72%, chest 15%, abdomen 11%	NA	NA	Riding schools: 11-15 yrs Competition riders: 16-20 yrs	Falls 49%, kicks 16%, trampling 4%, horse rolling over 9%, miscellaneous 16%	68% falls in public places	59% had <6 yrs experience	Increased risk with younger horses, horses >148 cm, Less risk trotting

(*continued on next page*)

Table 1 (*continued*)

Author(s) and year of publication (Country period of data collection)	Accident rate per 100,000 people	Female (%)	Most frequent injury	Most frequent site of injury	Severity (ISS[a] score)	Hospitalization-related statistics	Age group features (years)	Most common mechanism of injury	Context	Rider-related features	Horse-related features
Loder 2008 (retrospective NEISS system analysis USA 2002-2004)		66	Contusions/ abrasions 30.8%, fractures 28.3%, sprains/strains 17.6%, brain injuries 11.6%, lacerations 5.6%	Head and neck 28.9%, upper extremities 29.7%, lower extremities 16.4%, multiple body locations 1.1%			Average age 30.0 ± 17 yrs (33.8% <18 yrs)	Fall 58.7%, thrown or bucked from horse 22%, riding 8.6%, stepped or rolled on by horse 3.8%, kicked by horse 2.3%, performing ground care 1.9%, while mounting horse 1.8%, dragged by horse 0.4%, horse vs. motor vehicle 0.2%, shoeing horse 0.1%, miscella-neous 0.4%	At home 35.9%, recreation/ sporting facility 30.4%, on farm 18.5%, public property 12.3%, street or high-way 2.5%, school 0.5%		
Mayberry et al., 2007 (Retrospective survey of riders USA, 2003)		84	Bruises/ lacerations 46%, fractures 18%	Extremity 64%, chest 18%, face/ scalp 16%, brain 9%, neck 9%, spinal cord 3%, abdomen 3%, pelvis 2%			Median age, 44			*Riding skill level:* Novice 9.9%, intermediate 40.4%, advanced 36.5%, instructor or professional 12.4% High incidence of injury in first 18 hours of experi-ence then abrupt reduction by 80% at 100 hours. Near zero incidence at 5000 hours	
Moss et al., 2002 (United Kingdom, Surrey, 2000-2001)		**85**	**Fractures**	**Upper limb 29.2%, lower limb 22.3%, head 17.3%, multiple 11.2%, thoracolumbar 10.8%, pelvis 5%, neck 3.1%, abdomen 1.2%**			**Median age: 26**	**Falls 78.5%, kicks 11.1%, bites 0.8%, trodden on 5.4%, injury while leading horse 3.1%**			

Nelson and Bixby-Hammett, 1992 (Review of English language literature 1966-1991 mortality and hospital admission reviews)		Females predominate in mortality data (80% and 89%) and hospital admission data 68%-85%. Females suffer more injuries than males 52%-87%	Fractures 28%-48%	Upper extremities (30%-61%), head (10%-28%)			10-19 yrs	Falls[c]		
Newton and Nielsen, 2005 (Colorado, 2000-2003)		**38**	**Fractures**		**Average 8.5**	**Average hospital stay 72 hours**	**36-55 age range highest representation**	**Falls from horse 74%, stepped on by horse 9%, horse rolled on person 11%, head hit horse 2%, other 2%**	**70% incidents occurred during recreational pursuits, 68% were injured riding or tending rental horses**	**80% incidents due to loose cinches and saddle slip. *Rider carelessness, mismatching horse to rider*: Beginners: 55%, Novices: 10%, Experienced riders: 35%**
Smartt and Chalmers, 2009 (New Zealand, 2002-2003)	**233 per 100,000 but when include only "regular riders[d]", rate rises to 469 per 100,000. In 13-15 age group rises to 900 per 100,000**	66	**Fractures/ dislocations of limb and girdle bones followed by skull, spine and pelvic bones**	**Head and neck 23%, abdomen or lower back 18%, lower leg 17%.**			**Median age, 31 but female cases younger (median 28 yrs vs. 38 yrs for males) 10-14 yrs age group highest number of incidents**	***Riders*: Falls 70% *Bystander/ handlers*: Bitten/struck by horse 20%**	**41% during sport or leisure activities, 98.2% all cases were sustained during horse riding with <2% attributed to horse racing, polo and rodeo. Place of occurrence unspecified (32%), 24% on farm, only 1% were reported in a school**	
Sorli, 2000 (Review of health and coroner databases British Columbia, Canada, 1991-1996)		62	Fractures	Head 20%, upper limb 19%, lower limb, 18%, trunk 18%, spine 7%, unspecified makes up remainder[a]			25%: <10, 36%: 16-34, 37%: 35-83			

(*continued on next page*)

Table 1 (*continued*)

Author(s) and year of publication (Country period of data collection)	Accident rate per 100,000 people	Female (%)	Most frequent injury	Most frequent site of injury	Severity (ISS[a] score)	Hospitalization-related statistics	Age group features (years)	Most common mechanism of injury	Context	Rider-related features	Horse-related features
Thomas et al., 2006 (Review of NEISS data USA 2001-2003)	**35.7 per 100,000 population p.a.**	**59**	**Contusions/abrasions 31.4%, fractures 25.2%, strains/sprains 15.8%, concussion/internal head injury 9.7%, lacerations 7.7%, haematoma1.8%, dislocations 1.8%, other/unknown 6.6%**	**Head/neck 22.3%, upper trunk 17.7%, lower trunk 14.6%, upper extremities 21.5%, lower extremities 22.2%, other 0.9%**			**12% 10-14, 9.8% 15-19, 10.3% 35-39, 11.5% 40-44**	**Fall 78.9%, struck by or against 24%, crush 13.2%, overexertion 5.3%, bite 1.7%, other 0.7%**			
Williams and Ashby, 1995 (Victoria, Australia, collection periods varied by hospital but were in the period 1988-1995)	**16 (whole state = 18)**	**Of cases involving children: 77 Of cases involving adults: 59**	**Fractures followed by soft-tissue injury. Fractures accounted for 43% of child injuries and 30% of adult injuries; soft-tissue injuries 335 child injuries and 29% adult injuries**	**Upper limbs (50% children, 34% adults), lower limbs (17% children, 27% adults), head and face (22% children, 20% adults), rib fractures (4% of adults only), face and scalp 4%**		**27% (but 48% in total required referral or review after initial consultation in ER)**	**10-19yrs**	**Falls (77% of all cases), crushes—horse rolled on or stood on victim (7%), kicks (4%), rider being dragged (2%)**	**Accidents more common in warmer months, field/paddock most common site of incident. Horse behavior largest factor in accident (39%)**	**97% of cases occurred when riding the horse**	**Horse behavior given as factor in 61% accidents involving children (compared with 39% of those involving adults)**
As above, retrospective study 1991-1993		56		Extremities, then head or spine, then trunk		24%				Professional: 76% Recreational: 24%	

Bold entries include data on handler injuries.

[a]Injury Severity Score.

[b]All patients reported wearing a helmet at the time of injury but, as noted by the authors, helmets do not protect the face.

[c]Unable to determine if some of these injuries occurred during handling rather than riding.

[d]"Regular riders" being defined in this study as children over 5 years and adults who had ridden at any time in the last month.

their study, horses had a median age of 7 years and between 0 to 60 months of training. Both Ball et al. (2007) and Newton and Nielsen (2005) retrospectively interviewed patients about the accidents and therefore provided information on the cause of those accidents. The causes they listed included horse having "spooked," horse not having been trained for riders' "input demands," bad temperament (presumably of the horse), equipment failure (including loose girths/cinches), rider inexperience or carelessness, and the rider "simply having fallen."

In a study by Ball et al. (2007), riders had a mean of 27 years experience. In contrast, Ng and Chung (2004) and Abu-Zidan and Rao (2003) found no association between rate of hospital admission and a rider's status (leisure or professional), previous riding or injury experiences, or presence of supervision at the time of riding. Similarly, Kriss and Kriss's report (1997) also showed no correlation between victims' age, gender, or level of experience.

Common injuries

The areas of the body most vulnerable to horse-related injury are the head, hand or wrist, foot or ankle, and spinal cord or vertebral column. There is some evidence that older riders may be more vulnerable to thoracic injury. Contusions, abrasions, and fractures figure prominently. Concussion and brain injury were reported commonly in studies in which helmet usage was limited.

Effect of personal protective equipment

More recent articles found that improvements in helmet design and greater acceptance of the need to wear helmets when riding have helped to reduce the number of head traumas arising from horse-related accidents (Chitnavis et al., 1996; Moss et al., 2002; Abu-Zidan and Rao, 2003; Lim et al., 2003; Mayberry et al., 2007). There was some evidence that helmeted riders may sustain more facial injuries (Lim et al., 2003). Several articles predicted that the advent and adoption of protective vests may contribute to a drop in trunk injuries (Ball et al., 2007; Kiss et al., 2008; Bilaniuk et al., 2009), but the effectiveness of these vests has not been fully evaluated (Thomas et al., 2006). Protective footwear that provides ankle support has also been advocated to prevent ankle and foot injuries associated with horse-related incidents (Ceroni et al., 2007).

Injury-prevention strategies

A summary of prevention strategies proposed by the authors of articles within the current review appears in Table 5. Lucas et al. (2009) also suggested that personal protective equipment, such as helmets and vests, may prevent serious injury to veterinarians treating horses.

Discussion

Generally, the studies considered in the current review agree that horse-riding and handling are dangerous activities. Factors contributing to the inherent dangers of contact with horses include the size and unpredictable nature of horses, elevation of riders on horseback well above the ground, the kicking force of the horse, which is estimated to be approximately 1,000 N, and the speed of horses (up to 65 km/hr).

There was agreement that horse-related incidents can lead to a wide range of injuries, from mild contusions to death. Kiss et al. (2008) noted that one quarter of all lethal sport injuries in children are caused by horse-riding, whereas Ceroni (2007) concurred with the previous research, reporting that horse-riders can expect to be involved in a serious accident once in every 350 hours of contact time. In contrast, motor-cyclists have an expected rate of 1 serious accident every 7,000 hours. Furthermore, horse-riding injuries were responsible for significant numbers of hospital admittance days across the studies. Ten of the articles listed hospital admissions, with 5 specifying average hospital stays of 3 days or more (Cripps, 2000; Newton and Nielsen, 2005; Ball et al., 2007; Kiss et al., 2008; Cuenca et al., 2009).

Several studies reported a horse-related accident rate ranging from 16 to 233 per 100,000 people (Williams and Ashby, 1995; Jagodzinski and DeMuri, 2005; Smartt and Chalmers, 2009). When only "regular riders" were included, the rate rose to 469 per 100,000 (Smartt and Chalmers, 2009). This compares with a dog-related injury rates of 12.1 per 100,000 for males and 10.4 per 100,000 for females (Renate and James, 2005). Despite the higher injury rate associated with horses, there is a glaring omission of legislation covering horse-related activities in many countries (Fleming et al., 2001; Thomas et al., 2006), even though legislation designed to mitigate injury exists for apparently less common motor-cycle or dog-related incidents.

Demographics of those injured

The age- and gender-related distribution of horse-related accidents may simply reflect the demographics of the riding population. Figures from the Australian Bureau of Statistics show that the highest percentage of adults riding horses coincides with the highest frequency of adult injuries in the fourth and fifth decades of life. The ratio of females to males (6:1) aged <15 years participating in horse-riding activities, as reported in 4901.0 Children's Participation in Cultural and Leisure Activities (ABS, 2009) corresponds broadly to the ratio of injuries to females and males found in several of the articles covering this age group (Table 3).

Novice riders in their first 100 hours of riding appear to be at more risk of horse-related injury (Mayberry et al., 2007) and this would account for the high number of females in the 10 to 14 years age group represented in many of the studies, as presumably many children are beginning their riding careers in this period. It does not account for handling and riding injuries being more common among horse-owning human beings, or explain why males, especially those in their fourth or fifth decade, should be more likely to suffer serious injury than females in the same age group. Cuenca et al. (2009) noted that younger males in their study were less likely to wear helmets or other safety gear. Perhaps, older males take more risks or ride the more unpredictable animals. Williams and Ashby (1995) also suggest that higher representation of males in the 40- to 49-year age group is a reflection of occupational injury. Several studies found that experience did not necessarily moderate the severity of injuries and that risk of serious injury, including those among veterinarians, could be a function of cumulative exposure (Ball et al., 2007; Loder, 2008; Lucas et al., 2009). Arguably, experience in itself would not be preventative if new knowledge has not been incorporated into practice. Alternatively, it would be useful to identify if more experienced horse-riders and handlers are exposed to more reactive horses as part of their cumulative exposure.

If serious injury is a likely result of exposure to horses, then the centuries of horse management, training, and education to date appear to have done little to prevent injuries to human beings in their interactions with equids.

McGreevy et al. (2009) argue that because riding horses has no biological analogues in nature, riders and trainers must use learning theory and novel interspecific signals to control the horse under saddle. This underpins the importance of consistent and well-timed signals to elicit clear locomotory responses in the horse and the need to minimize horses' autonomy when they are ridden or handled. Failure to do so will result in ethologically predictable, but potentially very dangerous, flight or fight responses to permeate the ridden (and handled) horse's behavior. Confusion among horses can often result when novice riders, who have yet to develop adequate skills, body control, or balance, apply pressure signals that are inconsistent and independent of attempts to stay on-board. Furthermore, to be safe when ridden, horses must be under the control of interspecies signaling system rather than environmental stimuli. The good news is that there appears to be only a small number of signals from human beings that are required to cue even the most elaborate equine responses (e.g., in elite level equestrian sport).

Causes of injuries

There are many reasons that a rider may fall from a horse. Sometimes the rider simply loses balance. The growing understanding of the influence of the rider on the horse's stability and balance (Peham et al., 2004; Lagarde et al., 2005; Peham et al., 2008; Symes and Ellis, 2009) has yet to be acknowledged in published data on horse-related injury. There is no current reliable measure of what constitutes a secure seat or how this can be evaluated. Being physically capable of controlling reins does not necessarily confer immediate control of the horse if the horse has not been trained to respond to the negative reinforcement mechanisms that rein pressure is intended to elicit. Changes in the horse's gait and direction unforeseen by the rider can also unseat the rider.

Poor stimulus control of the horse by the rider and activation of the flight response are two aspects of horse–rider interactions that warrant further investigation as a means of preventing or mitigating horse-related accidents (McGreevy and McLean, 2007). Records of the type of apparatus being used at the time of any injury may assist in analyzing the controllable aspects of the horse–rider interaction. Avoidance of severe bits may at first glance seem to reduce the rider's control. However, it may also speak of the need for stronger bits as a result of habituation to milder ones. A more thorough understanding of bit mechanism and its role in negative reinforcement reveals how habituation to bit pressure actually makes the horse's response more unpredictable. Any move toward milder biting apparatus must be accompanied by an improved understanding of learning theory (Warren-Smith and McGreevy, 2008). In the long-term, the use of modern materials, such as "smart textiles" that are self-tightening (for cinches) or "memory foam," may lead to the development of safer equipment than is currently available.

The finding that the "galloping gaits" are associated with more accidents is not surprising; not only do they involve higher velocity, but the biomechanics of these gaits dictate that the rider experiences forces in the medial/lateral as well as in the cranial/caudal plane (Johnston et al., 2004; Lagarde et al., 2005; Lovett et al., 2005).

Handlers, including veterinarians, and bystanders are most commonly injured by horse kicks. Kicking is a normal part of the equid ethogram (McDonnell and Haviland, 1995) and one of the few active defense mechanisms that the horse possesses to deter aversive stimuli. In very young foals, the kick is a reflex response to pressure on the plantar aspect of the hind limb (Waring, 2003). A kick is, therefore, potentially the usual response to a stimulus that is unidentified or alarming. Horses may have to actively learn to suppress this natural behavior through habituation or operant conditioning when a human being is in close proximity to their hind limbs. The behavior of the human being sometimes overrides this habituation (e.g., when administering a needle or appearing suddenly behind a horse) so that the horse becomes more likely to kick.

Effect of personal protective equipment

Personal protective equipment has reduced the severity of some horse-related injuries among riders. Equipment, such as helmets (particularly those with face guards) and protective vests, could also reduce injuries to horse handlers

Table 2 Summary of articles covering adults only

Author(s) and year of publication (Country period of data collection)	Female (%)	Death rate	Most frequent injury	Most frequent site of injury	Severity (ISS[a] score)	Hospitalization	Mean age group (years)	Most common mechanism of injury	Context	Rider-related features	Horse-related features
Ball et al., 2007 (Canada 1995-2005)	40	7%	Fractures, pneumothoraces and hemothoraces	Chest 54%, head 48%, abdomen 22%, skull 18%, extremity fractures 17%, spinal fractures 17%, pelvic fractures 15%, spinal cord 6%, neck 1%	Mean 20 (required a ISS >12 to be admitted to study)	13 days	47	60% falling from horse, 16% crushed by falling horse, 8% kicked, 4% stepped on, 13% other[b]	Outdoors 88%, wide open spaces 45%, dry dirt 38%, uncultivated land 37%, sunny 87%, summer 55%, afternoons 53%	Mean 27 yrs experience, rode Western style. 6% riders <1 yr experience, 47% riders had been injured previously	Horse median age 7 yrs and training range 0-60 months. Horse "spooked" 35%, not trained for rider's input demands 27%, bad temperament 15%, simply fell 12%, equipment failure 6%, rider inexperience 5%
Johns et al., 2004 (retrospective study hospital admissions Auckland, New Zealand, 1994-2001)	76	Only fatalities studied		Soft tissue 29% Upper extremities 25%, lower extremities 24%, head 19%	Mean 5		34	29% falling from horse, 17% thrown from horse, 23% crushed by horse, 18% kicked[b]		Leisure riders predominate	
Ng and Chung, 2004 (prospective study Hong Kong, 2002)			**Minor injuries 60%, fractures and dislocations 29.1%**	**Upper limb injuries 23.6%**			**33**	**Riders: falling from horse 60%, non-riding 72%, kicked or trodden on 7%**		**No association between rider's status, previous riding or injury experiences or presence of supervision at time of riding with rate of admission**	
Clarke et al., 2008 (Ohio, 1993-2004)	**50**	**7%**	**Orthopedics 19%, neurosurgery 6%, general surgery 5%, urology/ vascular 8%**	**Head and face 38%, thoracic 26%, spinal column or cord 22%, pelvis 21%, extremity injuries 21%**	**35 ± 8 in non survivors**	**15.5 surgery patients, 12.3 non-surgery patients**	**42**	**Fall from horse 68%, crush 12%, kicked 8%, trampled on 5% (interpreted from graph)**		**Novice riders (i.e., <100 hours riding) more vulnerable to accident**	

Bold entries include data on handler injuries.
[a]There was trend for kick injuries to occur at work rather than in the leisure-riding environment.
[b]Unable to determine if some of these injuries occurred during handling rather than riding.

Table 3 Summary of articles covering children only

Author(s) and year of publication (Country period of data collection)	Female (%)	Most frequent injury	Most frequent site of injury	Hospitalization	Age-related data (years)	Most common mechanism of injury	Context	Rider-related features	Horse-related features
Jagodzinski and DeMuri, 2005 (USA 2002)	**62 except more males in <4 yrs age group**	**Contusions/ abrasions 28.6%, fractures 27.7%**	**Head and face 38%, upper extremities 24%, lower extremities 20%, chest 9%, abdomen 8%, pelvis 4%, neck/cervical spine 4%, back/thoracolumbar spine 8%**			***Mounted*: Falls from horse 52%, fell off and kicked 4%, fell off and stepped on 4%, fell off and dragged, entrapped or other 5% *Unmounted*: kicked 29%, stepped on by horse 4%, crushed or dragged by horse 2%**	**Sporting venues most common, followed by home**	***Risk factors*: Female OR (odds ratio) = 1.81, English-style riding OR = 1.77, riding 15-24 hours per month OR = 2.04**	
Kiss et al., 2008 (Hungary, Austria 1999-2003)	**90**	**Contusions**	***Riding*: Head/neck 24%, upper arm 14%, forearm 6%, wrist/ hand17%, trunk 22%, lower leg 4%, ankle foot 12%, *Handling*: Head/neck 19%, upper arm 45%, forearm 15%, wrist/ hand 19%, trunk 24%, lower leg 4%, ankle foot 15%**	**Children with familiar horse average hospital stay 2.88 days Children with unfamiliar horse average hospital stay 7.33 days**	**Mean age: 11**	**Falling from horseback 70.5%, falls with horse 6.3%, kicks 0.8%, bites 4.5%, collision 2.7%, trampling 2.7%, other 3.6%**		**Incidents typically occur 3 yrs after first horse-riding experience**	**Ownership of horse associated with more injuries during handling but injuries associated with riding more common if children did not own horse**
Cuenca et al., 2009 (Florida, 11-yr period)	82, although boys more likely to have polytrauma	Lacerations and contusions 58%, orthopedic 31%	Orthopedic 34%, Head 23%, Abdominal 21%, Chest 11%, Multiple 13%	50% required admission (64% without helmets vs. 39%, with helmets). Average stay 4 days	Median age: 12			82% falling or thrown, 6% kicked, trampled or trapped under animal[a]	12% during competition

Bold entries include data on handler injuries.
[a]Unable to determine whether some of these injuries occurred during handling rather than riding.

Table 4 Injuries to equine veterinarians

Author(s) and year of publication (Country period of data collection)	Female (%)	Most common place of injury	Most common activity at time of injury	Most frequent nature of injury	Most frequent site of injury	Treatment received	Mean period lost from work (days)	Use of safety precautions	Most common mechanism of injury
Landercasper et al., 1988 (Retrospective survey, Minnesota, Wisconsin.)	20			Lacerations	Hand		8.5		Kick
Lucas et al., 2009 (Retrospective survey, Australia. 1960-2000)	26	37.7% in stock or handling yards, 36.6% open paddock, 15.7% stables	Surgical (wound care, gelding) and medical procedures (nasogastric tubing)	Dislocations and fractures of face and/or thorax	Lower extremities 33%, head and neck 26%	18.8% hospital admission, 17.4% emergency room treatment only	7.4	34% used restraint of horse	Kicked or struck by horse (79%)

and bystanders. However, it should be noted that even current "gold-standard" helmets are not designed to withstand the focused force within a direct blow from a horse kick. Despite the undeniable evidence that wearing personal protective equipment does reduce the severity of horse-related injury, some authors noted a resistance to do so among certain riders (Ball et al., 2007). It is unclear whether this resistance is cultural or based on factors such as personal comfort. Extremity injuries may be reduced through the use of protective equipment, such as pads and gloves, similar to those designed for motorcycle racing. That said, personal protective equipment is effective only in mitigating the damage that can be incurred. Of course, it does not prevent the dangerous situation arising in the first place.

Preventative strategies

The "unpredictable" nature of horses is commonly cited as a cause of human injury. Recent advances in ethology and equitation science may make horse behavior more predictable (McLean and McGreevy, 2010). A clear understanding of the probable behavior patterns a horse can exhibit in a given context would help riders and handlers to predict and manage such behaviors. Horse trainers may be able to address this aspect of horse behavior through a more thorough application of current advances in learning theory (McLean, 2008; McLean and McLean, 2008).

We question the practicality of some of the preventative suggestions listed in Table 5. The concept of close supervision is laudable but, in practice, a horse that is shying, bucking, rearing, or bolting, (i.e., displaying flight responses) will not respond safely to indirect instruction or intervention by even the most experienced supervisor. The only supervisors who could be effective in these circumstances would have some control of the horse through a long rein or lead and would need considerable knowledge and skill. Similarly, indoor facilities are not always available and it seems impractical to ask riders to stay indoors and avoid "unsuitable" terrain until they have accrued 3 years of experience. Finally, it is obviously impossible to "avoid hind legs of horses at all times."

As horse behavior figures so prominently as a precipitating factor in as many as 61% of incidents (Williams and Ashby, 1995), consideration of variables associated with the horses must form the foundation of effective injury prevention and mitigation. We agree with Nelson and Bixby-Hammett (1992) that further research for data on safety around the breed and training of the horse are needed. Application of recently developed knowledge on breed-typical behavior (Lloyd et al., 2008) could help horse-riders and trainers make informed choices on the suitability of certain breeds for work requirements. Breeds that score lower on anxiousness and excitability presumably make better mounts for novice (and therefore unpredictable) riders. Ingemarson et al. (1989) observed that young horses are

Table 5 Accident-prevention strategies identified by authors in articles on horse-related injuries in humans

Horse-related factors	Rider-/handler-related factors	Parental/instructor factors	Equipment factors	Environmental factors
Horse fed and watered	Children to be developmentally capable of a secure seat and to control extremities in order to control horse through reins	Close parental supervision of children	Regular thorough checking of tack. Saddle fit should be snug and stirrup size appropriate for rider	Avoid excessively soft or muddy ground and ditches, holes, and uneven terrain with rocks or exercise caution if these surfaces are unavoidable
Smaller horses, temperament of horse	Training in horse safety (e.g., horse behavior, falling techniques, banning wrapping reins or leads around limbs or neck)	Good knowledge of horses and their behavior	Safety stirrups should be used	Riders to be limited to indoor schools until greater than 3 yrs' experience
Avoid hindlegs of horses at all times	Rider's skill level matched to appropriate horse (e.g., novice riders on horses older than 5 yrs)	Parental training schemes in horse behavior and risks involved	Avoid bareback riding	
	Children to be warned of horse "danger zones"		Personal protective equipment to be used when riding and handling horses (e.g., mouth-guards, face-shields, non-stick protective gloves), appropriate footwear (e.g., support the ankle, smooth soles, definite heel), safety vests/chest protectors, approved helmets, adoption of wrist protectors	
	Senior riders should take steps to prevent osteoporosis			
	Avoid alcohol consumption before and during horse activities			

more commonly associated with accidents, implying that older horses behave differently. In learning theory terms, it would be appropriate to conclude that older horses are more habituated to their environment or in optimal practice have well-consolidated and reliable responses and are therefore less reactive. This would be perceived as their behavior being more predictable. Alternatively, horses that have behaved too unpredictably (as perceived by their human handlers) may have been culled from the riding population over time. This possibility is reflected in Ödberg and Bouissou's (1999) study showing that wastage in young horses is often because of perceived behavioral problems. We can only speculate that taller horses are associated more with serious injury (Ingemarson et al., 1989) because there is farther to fall.

Recent advances in applying learning theory to horses contradict Mayberry et al.'s (2007) view that horses cannot be fully tamed. Horses with poorly trained acceleration and deceleration responses, both in-hand and under-saddle, show a positive correlation with unpredictable hyper-reactive and conflict behaviors (especially elements of the flight response). Retraining of basic operant responses must form part of everyday horse–human interactions to reinforce obedient and predictable equine behavior (McLean, 2005). An understanding by riders, instructors, and parents of the role of learning theory and desensitization in horse-training (Christensen et al., 2006; McLean, 2008) would also reduce conflict and confusion in the horse and rider/handler dyad. The same can be said for practical application of knowledge about the action and effect of equipment on horses (Quick and Warren-Smith, 2009; Meschan et al., 2007). Keeling et al.'s (2009) recent study showed that horses appear to be affected by the arousal state of their riders or handlers. The rider also influences a horse's gaits (Peham et al., 2004) and may play an underestimated role in disturbing the horse's centre of balance causing the horse to stumble or become less predictable in its gaits. Many of the preventative strategies suggested by the articles reviewed here call for more training in horse behavior for horse-riders and handlers. This should include evidence-based explanations of learning theory and equine ethology (McGreevy et al., 2009). Just as horses and riders cannot be considered as separate entities when assessing performance, strategies for preventing injuries must always include the equine member of the dyad.

Conclusions

Horse-related injuries to human beings are relatively common, and unfortunately, can have a profound effect on the quality of life of the injured human being. Numerous studies over the past 2 decades have reported factors as recorded by medical staff that may have contributed to incidents involving horses. However, generally collation of horse-related factors is only limited in these studies and verification of the horse's behavior and the specific stimuli to which it was responding in the context of the incident is virtually absent. We propose that, in light of the increasing body of knowledge related to horse behavior, emphasis should be placed on the epidemiology of horse behavior in horse-related accidents so that more effective preventative strategies can be implemented. Such strategies should include incorporating learning theory principles into horse and rider training to reduce flight and defense responses in horses (particularly in those destined for novice and child riders and handlers), and the generation of effective, verified, safety protocols when riding and handling horses. Legislation requiring the mandatory wearing of approved helmets and footwear should be encouraged. As equitation science gains currency as a way to study and improve horse welfare and performance, it is important to acknowledge the roles of equine ethology and learning theory in enhancing rider safety.

Acknowledgments

The authors gratefully acknowledge the assistance of Lynn Cole for her helpful comments on earlier drafts of this article. Lesley Hawson is supported by a grant from the Australian government's Rural Industries Research and Development Corporation and receives, in kind, support from the Australian Equine Behavior Centre, Australian Institute of Sport, Equestrian Australia, Horse South Australia, The Horse and Hoofbeats magazines, and Bates Saddlery.

References

ABS, 2007. 4177.0 Participation in sports and physical recreation, Australia, 2005-2006. Australian Government, Canberra, Australia.

ABS, 2009. 4901.0 children's participation in cultural and leisure activities, Australia, Apr 2009. Australian Government, Canberra, Australia.

Abu-Zidan, F.M., Rao, S., 2003. Factors affecting the severity of horse-related injuries. Injury 34, 897-900.

Ball, C.G., Ball, J., 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, 636-640.

Bilaniuk, J.W., Gage, A.M., Adams, J.M., Siegel, B.K., Cockburn, M.I., DiFazio, L.T., Allegra, J.R., 2009. Injury patterns are different for older and younger patients in equestrian accidents. J. Emerg. Med. 37, 219-220.

Ceroni, D., 2007. Support and safety features in preventing foot and ankle injuries in equestrian sports. Int. Sportmed. J. 8, 166-178.

Ceroni, D., De Rosa, V., De Coulon, G., Kaelin, A., 2007. The importance of proper shoe gear and safety stirrups in the prevention of equestrian foot injuries. J. Foot Ankle Surg. 46, 32-39.

Chitnavis, J.P., Gibbons, C.L., Hirigoyen, M., Parry, J.L., Simpson, A.H., 1996. Accidents with horses: what has changed in 20 years? Injury 27, 103-105.

Christensen, J.W., Rundgren, M., Olsson, K., 2006. Training methods for horses: habituation to a frightening stimulus. Equine Vet. J. 38, 439-443.

Clarke, C.N., Tsuei, B.J., Butler, K.L., 2008. Equine-related injury: a retrospective analysis of outcomes over a 10-year period. Am. J. Surg 195, 702-704.

Cripps, R.A., 2000. Horse-related injury in Australia. In: Australian injury prevention bulletin. Flinders University of Adelaide, Adelaide, Australia.

Cuenca, A.G., Wiggins, A., Chen, M.K., Kays, D.W., Islam, S., Beierle, E.A., 2009. Equestrian injuries in children. J. Pediatr. Surg. 44, 148-150.

Exadaktylos, A.K., Eggli, S., Inden, P., Zimmermann, H., 2002. Hoof kick injuries in unmounted equestrians. Improving accident analysis and prevention by introducing an accident and emergency based relational database. Emerg. Med. J. 19, 573-575.

Feh, C., de Mazières, J., 1993. Grooming at a preferred site reduces heart rate in horses. Anim. Behav. 46, 1191-1194.

Fleming, P.R., Crompton, J.L., Simpson, D.A., 2001. Neuro-ophthalmological sequelae of horse-related accidents. Clin. Exp. Ophthalmol. 29, 208-212.

Ingemarson, H., Grevsten, S., Thoren, L., 1989. Lethal horse-riding injuries. J. Trauma Injury Infect. Crit. Care 29, 25-30.

Jagodzinski, T., DeMuri, G.P., 2005. Horse-related injuries in children: a review. WMJ 104, 50-54.

Johns, E., Farrant, G., Civil, I., 2004. Animal-related injury in an urban New Zealand population. Injury 35, 1234-1238.

Johnston, C., Holm, K.R., Erichsen, C., Eksell, P., Drevemo, S., 2004. Kinematic evaluation of the back in fully functioning riding horses. Equine Vet. J. 36, 495-498.

Keeling, L.J., Jonare, L., Lanneborn, L., 2009. Investigating horse-human interactions: the effect of a nervous human. Vet. J. 181, 70-71.

Kiss, K., Swatek, P., Lenart, I., Mayr, J., Schmidt, B., Pinter, A., Hollwarth, M.E., 2008. Analysis of horse-related injuries in children. Pediatr. Surg. Int. 24, 1165-1169.

Kriss, T.C., Kriss, V.M., 1997. Equine-related neurosurgical trauma: a prospective series of 30 patients. J. Trauma Injury Infect. Crit. Care 43, 97-99.

Lagarde, J., Kelso, J.A., Peham, C., Licka, T., 2005. Coordination dynamics of the horse-rider system. J. Mot. Behav. 37, 418-424.

Landercasper, J., Cogbill, T.H., Strutt, P.J., Landercasper, B.O., 1988. Trauma and the veterinarian. J. Trauma 28, 1255-1259.

Lim, J., Puttaswamy, V., Gizzi, M., Christie, L., Croker, W., Crowe, P., 2003. Pattern of equestrian injuries presenting to a Sydney teaching hospital. A.N.Z.J. Surg. 73, 567-571.

Lloyd, A.S., Martin, J.E., Bornett-Gauci, H.L.I., Wilkinson, R.G., 2008. Horse personality: variation between breeds. Appl. Anim. Behav. Sci. 112, 369-383.

Loder, R.T., 2008. The demographics of equestrian-related injuries in the United States: injury patterns, orthopedic specific injuries, and avenues for injury prevention. J. Trauma Injury Infect. Crit. Care 65, 447-460.

Lovett, T., Hodson-Tole, E., Nankervis, K., 2005. A preliminary investigation of rider position during walk, trot and canter. Equine Comp. Exerc. Physiol. 2, 71-76.

Lucas, M., Day, L., Fritschi, L., 2009. Injuries to Australian veterinarians working with horses. Vet. Rec. 164, 207-209.

Mayberry, J.C., Pearson, T.E., Wiger, K.J., Diggs, B.S., Mullins, R.J., 2007. Equestrian injury prevention efforts need more attention to novice riders. J. Trauma Injury Infect. Crit. Care 62, 735-739.

McDonnell, S.M., Haviland, J.C., 1995. Agonistic ethogram of the equid bachelor band. Appl. Anim. Behav. Sci. 43, 147-188.

McGreevy, P., Hahn, C.N., McLean, A.N., 2004. Equine behavior: a guide for veterinarians and equine scientists. W.B. Saunders, Philadelphia, PA, pp. 369.

McGreevy, P.D., McLean, A.N., 2007. Roles of learning theory and ethology in equitation. J. Vet. Behav.: Clin. Appl. Res. 2, 108-118.

McGreevy, P.D., Oddie, C., Burton, F.L., McLean, A.N., 2009. The horse-human dyad: can we align horse training and handling activities with the equid social ethogram? Vet. J. 181, 12-18.

McLean, A., 2005. Behavior problems in the ridden and led horse - association with dysfunctions in negative reinforcement. In: Equine Ethology Conference. Nantes, France.

McLean, A.N., 2008. Overshadowing: a silver lining to a dark cloud in horse training. J. Appl. Anim. Welfare Sci. 11, 236-248.

McLean, A.N., McGreevy, P.D., 2010. Horse-training techniques that defy the principles of learning theory. J. Vet. Behav.: Clin. Appl. Res. 5, 187-195.

McLean, A., McLean, M., 2008. Academic horse training: equitation science in practice. AEBC, Clonbinane, Australia.

Meschan, E.M., Peham, C., Schobesberger, H., Licka, T.F., 2007. The influence of the width of the saddle tree on the forces and the pressure distribution under the saddle. Vet. J. 173, 578-584.

Moss, P.S., Wan, A., Whitlock, M.R., 2002. A changing pattern of injuries to horse riders. Emerg. Med. J. 19, 412-414.

Nelson, D.E., Bixby-Hammett, D., 1992. Equestrian injuries in children and young-adults. Am. J. Dis. Child. 146, 611-614.

Newton, A.M., Nielsen, A.M., 2005. A review of horse-related injuries in a rural colorado hospital: implications for outreach education. J. Emerg. Nurs. 31, 442-446.

Ng, C.P., Chung, C.H., 2004. Horse-related injuries: a local scene. Hong Kong J. Emerg. Med. 11, 133-141.

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. Suppl. 28, 26-30.

Peham, C., Hofmann, A., Molsner, J., Borkenhagen, B., Kuhnke, S., Baltacis, A., 2008. Forces acting on the horses back and the stability of the rider in sitting and rising trot—a comparison. Pferdeheilkunde 24, 337-342.

Peham, C., Licka, T., Schobesberger, H., Meschan, E., 2004. Influence of the rider on the variability of the equine gait. Hum. Mov. Sci. 23, 663-671.

Quick, J.S., Warren-Smith, A.K., 2009. Preliminary investigations of horses' (*Equus caballus*) responses to different bridles during foundation training. J. Vet. Behav.: Clin. Appl. Res. 4, 169-176.

Renate, K., James, H., 2005. Dog related injuries. AIHW National Injury Survelillance Unit, Adelaide, Australia.

Siebenga, J., Segers, M.J.M., Elzinga, M.J., Bakker, F.C., Haarman, H., Patka, P., 2006. Spine fractures caused by horse riding. Eur. Spine J. 15, 465-471.

Smartt, P., Chalmers, D., 2009. A new look at horse-related sport and recreational injury in New Zealand. J. Sci. Med. Sport 12, 376-382.

Sorli, J.M., 2000. Equestrian injuries: a five year review of hospital admissions in British Columbia, Canada. Injury Prev. 6, 59-61.

Symes, D., Ellis, R., 2009. A preliminary study into rider asymmetry within equitation. Vet. J. 181, 34-37.

Thomas, K.E., Annest, J.L., Gilchrist, J., Bixby-Hammett, D.M., 2006. Non-fatal horse related injuries treated in emergency departments in the United States, 2001-2003. Br.. J. Sports Med. 40, 619-626.

Waring, G.H., 2003. Horse behaviour, 2nd Ed. Noyes Publications William Andrew Publishing, Norwich, NY.

Warren-Smith, A.K., McGreevy, P.D., 2008. Preliminary investigations into the ethological relevance of round-pen (round-yard) training of horses. J. Appl. Anim. Welfare Sci. 11, 285-298.

Williams, F., Ashby, K., 1995. Horse related injuries. Monash University Accident Research Centre, Melbourne, Australia.