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Epidemiology of Equestrian Accidents: a Literature Review

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Epidemiology of Equestrian Accidents: a Literature Review

Purpose: This manuscript aimed to present a review of the literature pertaining to horse riding and other horse-related injuries.

Method: A review of the literature was performed, searching for appropriate terms with regards to horse accidents, horse riding injuries and protective clothing for the horse riding context. The literature review search returned 151 relevant full-text articles, with 71 of these detailing the overall injury epidemiology of horse-related accidents. Most of these studies were conducted in the USA and used a retrospective review of hospital data methodology.

Results: Of the 71 articles investigated, 60 suggested that those most frequently involved in horse-related accidents are young females and 97% of papers investigating injury mechanisms found the most commonly involved was a fall from horseback. It was suggested in multiple studies that these injury events mostly occurred in warm weather conditions, when the horse behaved in an unexpected manner. Injury type and location varied by the primary mechanism of injury; but frequently involved body regions were the head and upper extremities, and the most common injuries observed were fractures and soft tissue injuries. Neurological trauma was reported by all relevant studies to be the most frequent cause of fatality.

Conclusion: Some improvements in horse-related accident numbers and outcomes have been observed with the development and introduction of protective devices such as helmets and vests. Yet despite the benefits of helmet and vest usage, there is evidence to suggest helmets do not perform as well as they could. Further work could investigate improvements in safety measures and risk factors associated with fatalities.

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ABSTRACT

Purpose: This manuscript aimed to present a review of the literature pertaining to horse riding and other horse-related injuries. **Method:** A review of the literature was performed, searching for appropriate terms with regard to horse accidents, horse riding injuries and protective clothing for the horse riding context. The literature review search returned 151 relevant full-text articles, with 71 of these detailing the overall injury epidemiology of horse-related accidents. Most of these studies were conducted in the USA and used a retrospective review of hospital data methodology. **Results:** Of the 71 articles investigated, 60 suggested that those most frequently involved in horse-related accidents are young females and 97% of papers investigating injury mechanisms found the most commonly involved was a fall from horseback. It was suggested in multiple studies that these injury events mostly occurred in warm weather conditions, when the horse behaved in an unexpected manner. Injury type and location varied by the primary mechanism of injury, but frequently-involved body regions were the head and upper extremities, and the most common injuries observed were fractures and soft tissue injuries. Neurological trauma was reported by all relevant studies to be the most frequent cause of fatality. **Conclusion:** Some improvements in horse-related accident numbers and outcomes have been observed with the development and introduction of protective devices such as helmets and vests. Yet despite the benefits of helmet and vest usage, there is evidence to suggest helmets do not perform as well as they could. Further work could investigate improvements in safety measures and risk factors associated with fatalities.

Keywords: horse, riding, epidemiology, injuries, review

INTRODUCTION

Horse riding is a popular sport which is typically considered to be a leisure activity; yet the span of horse-related activities is broad, extending from farming to equestrian sports such as racing and eventing. The current horse population is estimated to exceed 5 million in the European Union and 1.2 million in Australia.[1,2] The number of horse riders in Britain was reported at 2.7 million in 2015, while in the USA, this figure was estimated at 8.09 million in 2013.[3,4]

Correspondingly, horse-related mishaps represent a sizeable proportion of those patients presenting to a hospital with injuries resulting from unintentional accidents, with one study reporting an overall incidence rate of 23.7 hospitalizations per 100,000 persons per year and an overall death rate of 0.17 per 100,000 persons per year.[5] In fact, it has been suggested that horse riding is more dangerous than motorcycle riding. A study Sorli in 2000 revealed a hospital admission rate of 0.49/1000 hours of horse riding compared to an admission rate of 0.14/1000 hours for motorcycle riding.[6] Paix (1999) also found that in horse racing, the injury incidence of 0.88% per competitor per event involved in eventing competitions in Australia exceeded the motorcycle injury incidence of 0.24% reported for motorcycle racing.[7,8]

Furthermore, horse riding has been found to be the second most common sports-related cause of hospitalizations in adults and was responsible for the highest proportions of insurance claims due to adventure sports activities in New Zealand, being two times greater than mountain biking and four times higher than tramping (going for long-distance walks in rough country), with three of the 27 fatalities due to horse riding accidents.[9,10] Compared to a variety of other sports, the long-term consequences of injuries were found to be the most prevalent in horse riding, soccer, and skiing.[9]

In Sweden, while decreasing trends in hospitalization rates have been observed for activities such as cycling, skiing, and snowboarding, equestrian accidents have remained relatively constant between the years 2001 and 2014.[11] In Israel, equestrian injury rates have increased, particularly in relation to pediatric involvement (from 25% to 44% between 1984 and 1996).[12] Horse-related injuries are also over-represented in farm accidents, being responsible for 73% of injuries in the farm setting and represent the greatest proportion of injured and fatal patients presenting to hospital in New Zealand due to animal-related injuries.[13,14]

These accidents represent a significant cost to the public health system globally, with a total cost for consultation and treatment per accident of €1400 per hospitalized patients in Sweden, an average cost per fall from a horse of NZ$3000 in New Zealand, and insurance claims cost in excess of AUD$6million per annum among licensed jockeys, track riders, and stable hands.[15-17]

Horse-related injuries represent a significant and persistent public health concern. To assess the current knowledge-base on horse-related accidents, we undertook a review of the literature available on horse-related accidents. The last known manuscript exploring the general epidemiology of horse-related injuries was conducted in 2010 by Havlik et al, and as such, it is important to provide an updated picture of the literature available.[18] This manuscript explores the current literature on the epidemiology of horse riding accidents and aimed to provide detailed information from a range of sources on the characteristics of injured riders, environmental factors, characteristics of injuries and fatalities, as well as current prevention and safety promotion measures.

METHODS

The Chalmers University library search engine was used to search all relevant articles from all available databases. Search terms “horse-related OR horse riding OR equestrian” AND “accident OR injury OR injuries” were used to identify all English-language studies pertaining to equestrian injury patterns. Additionally, studies which detailed protective clothing and other protection available to horse-riders were detected using search terms “horse rider OR equestrian” AND “protection OR helmet OR vest.”

A total of 151 relevant full text entries were returned. There were eight that were non-English based language references which were excluded. Manuscripts were also excluded if they did not contain specific mention of the injury outcome of horse accidents and six manuscripts were excluded as they focused on either rider falls from horseback or horse falls, without specifying the injury outcome of the riders.

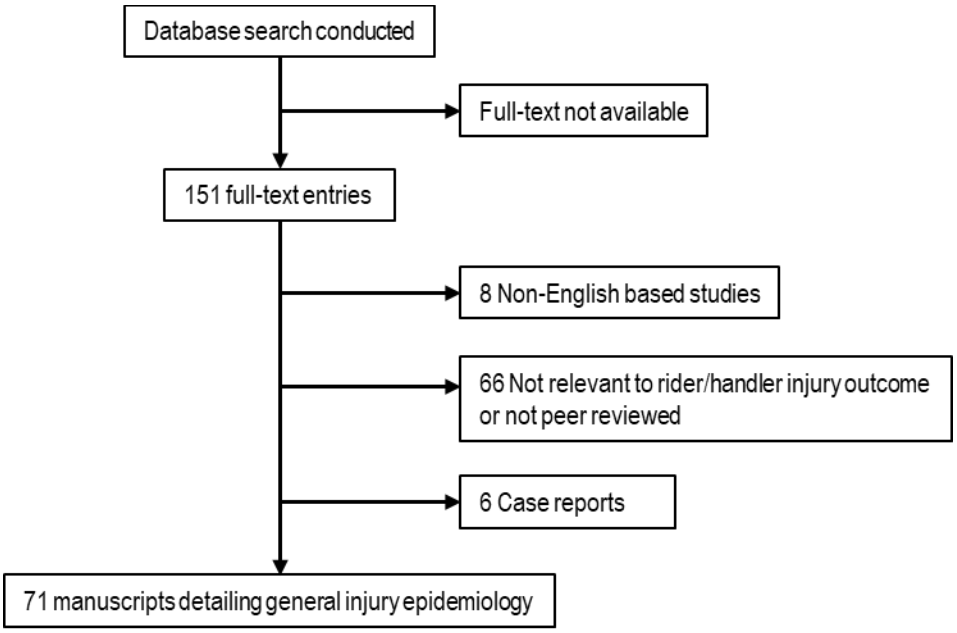

Figure 1. Consort diagram of literature review exclusion process

RESULTS

There were 71 manuscripts which detailed the general injury epidemiology of horse-related accidents. A further six studies, not included in this investigation, involved case reports of select patient outcomes and treatment protocols. The oldest study the search returned was published in 1973. The years 2007 and 2011 saw the most published articles, with 7% of the total number of studies published in each of these years. As can be seen in Figure 2, a sizeable proportion of the studies were from the USA (28.4%), Australia (12.3%) and the UK (12.3%).

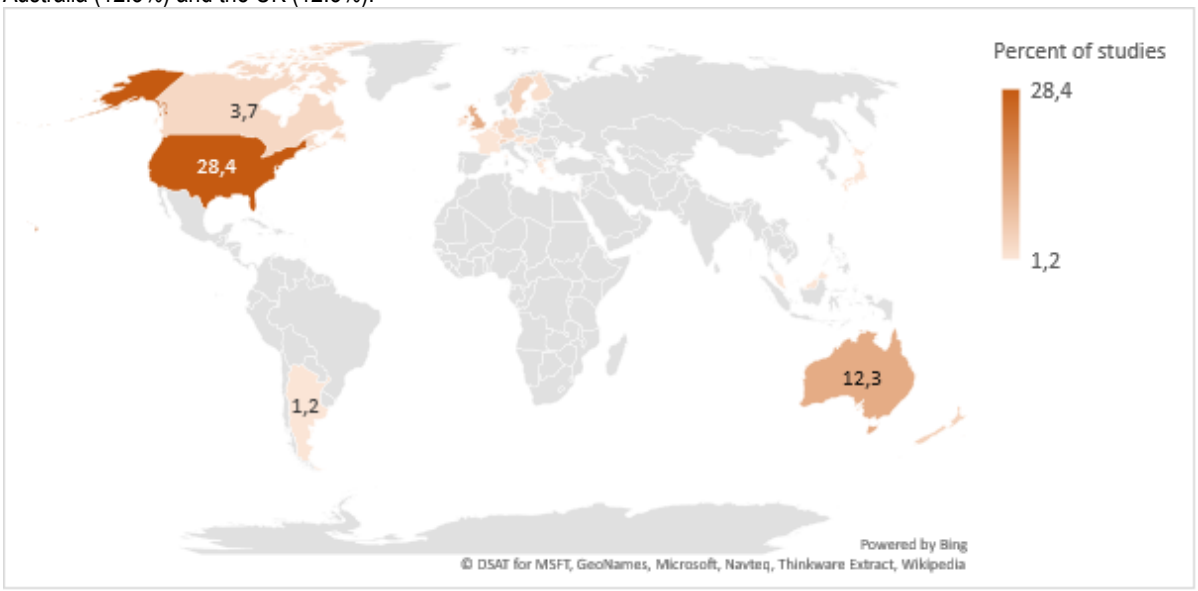

Figure 2. Illustration of distribution of study location among included papers.

The most common methodology involved a review of medical records (55 of the 71 studies), 10 of which involved a follow-up interview with the injured patient. A further two studies reviewed insurance accident information. On-site examination was conducted in only three of the 71 studies. There were nine cross-sectional investigations which involved self-report injury details.

An additional two studies utilized a case-control methodology to look at the difference between riders who suffered an accident verse those who did not, with one of these involving some analysis of retrospective data.

Four of the 71 studies specifically examined an adult sample of horse-related accidents, while eight investigated horse-related injuries in pediatric patients. The majority (n=63) of the studies investigated the overall injury pattern to the entire body, while four specifically examined spinal injuries, two detailed maxillofacial injury patterns, one looked at pelvic fractures and one at foot lesions. Five of the studies specifically investigated injuries to jockeys in horse racing, four detailed injuries during horse handling or while unmounted with one specifically in the veterinarian setting, three looked at injuries during eventing, three examined injuries only to those mounted at the time of the accident, one looked at injuries from polo and a final study looked at injuries while showjumping.

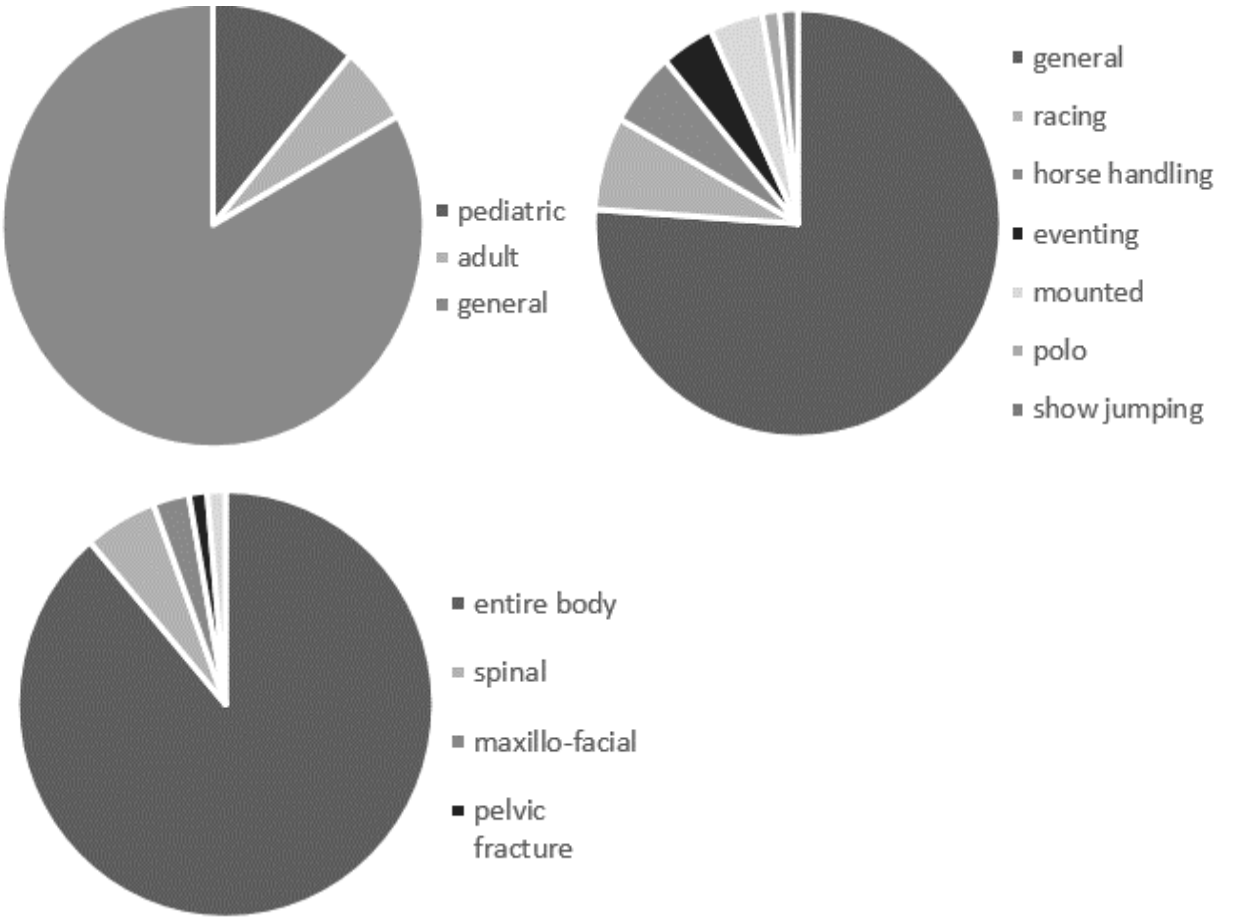

Figure 3. Distribution of studied age ranges (a), sport disciplines (b) and injuries (c)

Characteristics of Injured Riders

Gender. It has been widely reported that there is a strong gender bias in horse-related accidents, with females typically representing a significant proportion of those injured in these accidents.[19,20] In fact, 60 of the 71 epidemiological studies reviewed in this article stated that females dominated the sample of horse-related accidents. A study by Bentley et al investigated insurance claims in New Zealand and found that female horse riders had an estimated incidence rate of 34.5 per 1,000 annual participants, which was two-times that of male participants.[10] In the Netherlands, an investigation of patients hospitalized with spinal injuries from horse-related accidents found that females outnumbered males by a factor of seven and, when compared to other sporting injuries (rugby, trampolining, and gymnastics), horse riding was found to be the only sport with female predominance.[21,22] This may be representative of a predominance of women participating in the sport, with females found to represent 74% of the riding population in Britain in 2015.[3]

Age. Statistics show that there is also a bias towards younger age groups, with females particularly dominating in these age groups.[6,13,23-25] This age bias is of particular concern with the British Equestrian Trade Association, revealing a significant growth in the number of riders aged between 16 and 24, rising from 368,000 in 2011 to 403,000 in 2015.[3]

An early investigation of the Dumfries and Galloway Royal Infirmary hospital records (Scotland) found that 70% of patients with horse-related injuries presenting to hospital between 1977 to 1978 were female, and 50% were children under 15.[26] Similarly, in 1993, Buckley et al reported that in a retrospective sample of 827 equestrian accidents, both incidence and mortality rates for the whole population were 3.9% higher for females than for males in the 10 to 14-year age group.[5] Around the same time in Sweden, a retrospective review of horse riders presenting to hospital between 1983 and 1984 revealed that females predominated, with girls aged 9 to 12 years having the highest incidence of injury, followed by girls aged 13 to 19 years, being 15.8/1,000/year and 8.4/1,000/year respectively.[27] In 1996, Chitnavis et al discovered from a sample of 177 riders who presented to a hospital in London, that there was a three-to-one ratio of females to males, and the most commonly injured groups were females aged 10 to 20 (26%) and 20 to 30 (23%).[28] Specifically in relation to injury type, Cripps found that in a retrospective review of patients presenting to hospitals in Australia, female horse riders aged 10 to 14 years were at a high risk of injury from riding horses, with injury rates per 100,000 population for some injuries in females significantly higher in this age group than rates in males of the same age.[29] In 2008, Loder gave an account of a retrospective review which investigated 5,033 patients presenting to hospitals as a result of horse-related accidents between 2002 and 2004. In this investigation, females represented 66% of the overall sample, with a substantial proportion of these females being in their second decade.[30] Also, in the USA, Guyton et al retrospectively reviewed hospital records for horse-related accidents and reported a prominent spike of female predominance in the 10 to 19-year age range.[31]

While there is overwhelming evidence to suggest that young females predominate those involved in horse-related accidents, Smartt and Chalmers also highlighted other rider groups which may be at a high risk of being involved in horse-related accidents.[16] This study was conducted in New Zealand; 716 compensation claims from patients involved in equestrian accidents between 2002 and 2003 were investigated. Consistent with other experimental results, 66% of participants were female and the largest proportion were in the 10 to 14-year age group. However, injury rates rose steadily after the age of 34 years, and the 50 to 64 years age-group approached that of the 13 to 15-year-olds. After the age of 64 years, the injury rate exceeded that of all other groups, but the overall number of cases was small (n=21) and the confidence intervals wide. Similarly, in a sample of 284 equestrian accidents, Bilaniuk et al discovered that not only were there peaks in the 6 and 10 year age groups, there was also a peak in the 45 year old age group.[32] A study by Petridou et al reported that while riders injured during equestrian sports and horse racing were all under the age of 54, 70% those injured during farming activities were among adults aged 55 years and older.[33] This sample of 244 participants were adults presenting to hospitals for horse-related injuries in Greece between 1996 and 2000, and the investigators suggested that this reflected the farming population in the region.

Males and horse-related injury events. Other investigations have found a dominance of injuries among male riders overall. This dominance was typically due to the specific demographic of the country or the activity investigated. Swanberg et al found in multiple investigations that men were more frequently involved in horse-related accidents in the Latino thoroughbred farm setting.[34,35] Likewise, a study of professional equestrians presenting to hospitals in Hong Kong due to horse-riding accidents found a higher frequency of men reporting to hospitals with a male-to-female ratio of 8:1. In Japan, a similar scenario was observed, with 73% of patients presenting to hospitals for injuries incurred during horse-handling were men.[36] In the pediatric setting, several investigations have found that in the very young age groups (up to 5 years), boys either equaled or outnumbered the girls in injuries, even if the girls still significantly predominated in the older age groups.[37,38]

Aside from the pediatric setting, males injured in horse-related accidents tend to be of a more advanced age than their female counterparts.[14,39-44] Moreover, in the older age groups, males often outnumber females. In Australia in 2014, Papachristos et al presented a report on a retrospective review of hospital data on adult horse-related injuries.[45] This study found that males dominated in the over 54-year-old age group. Similarly, Northey found that, while females accounted for 35% of injuries in the 10 to 19-year-old age group, males were more frequently presenting to hospitals for horse-related injuries than were females for those patients aged over 50 years old.[46] Thomas et al found that in a sample of 102,904 people injured as a result of horse-related accidents in the USA, female injury rates peaked at 10 to 14 years, being three times the injury rate of men in this age group.[47] However, males had higher injury rates than females in the over 55-year-old age group. Williams and Ashby retrospectively investigated 1,068 cases of hospitalized injuries resulting from horse riding accidents between 1988 and 1993.[48] This study involved data from five different hospitals in the study region. As with the aforementioned studies, females predominated both in child cases (77%) and adult cases (59%). However, males began to dominate slightly in the older age groups. They concluded that this may reflect the greater proportion of occupational injury cases presenting to this hospital, with males representing a larger number of occupational horse riders. In an early investigation from 1982 to 1984, Lloyd reported that out of the 237 hospital medical

records reviewed, 75 of these involved males, and 57% of these males were professional.[49] Additionally, Lim et al discovered that male equestrians outnumbered female equestrians in the professional group, whereas female equestrians outnumbered male equestrians in the recreational group.[50]

Weber et al investigated 679 hospital records from eight countries in the EU where patients presented to hospitals from horse-related accidents.[51] These were categorized by whether the participant had fallen off the horse, been kicked by the horse, been crushed by the horse, or was involved in a carriage accident. While the first three mechanisms affected mostly females (71.3 to 75.5%), carriage driving accidents predominantly involved males (73.3%). Additionally, the carriage drivers were found to have a more advanced mean age of 57 years.

The most frequently injured of all those involved in equestrian accidents are non-professionals and those of lesser experience.[28,44,52-56] Mayberry et al surveyed 679 members of equestrian organizations centered in Oregon, Washington, and Idaho in March 2003.[57] The questionnaire queried respondents on their equestrian discipline, skill level and whether they had ever suffered a horse-related injury to determine the influence that rider skill and experience have on injury risk. The incidence of "any injury" or "serious injury" (injury resulting in hospitalization, surgery, or disability) declined with advancing skill level. Additionally, the equestrian disciplines of hunting, jumping, and schooling were the only disciplines associated with an increased risk of injury.

Environmental factors. Silver and Parry described the typical horse related-accident as being unrelated to traffic conditions, occurring in the summer months (between December and March in the southern hemisphere), during fine weather, when a relatively inexperienced rider falls from an excitable mare stabled in an unapproved riding establishment.[58] This statement has been confirmed with other research suggesting horse accidents most frequently occur in the summer months[31,32,55,59,60] and in the afternoon with mild weather conditions.[59,60] In 2014, Bilaniuk et al found that there was, in fact, a statistically significant difference between the numbers of riders presenting to hospitals with equestrian injuries between the summer and winter months in the female cohort of riders.[32] The location of the accident has been reported to be most frequently occurring outdoors in an open field, on dirt or uncultivated land.[59,60] In 2017, Theodore et al discovered that in Australia, out of a total 171 horse-related accidents to children, 36.9% occurred at home or while at another private residence, and 26.2% occurred at a public riding facility.[38]

In 1995, Williams and Ashby presented similar findings in their retrospective review of 1,068 horse-related accidents.[48] Accidents more frequently occurred in the warmer months, and the most common accident locations were fields/paddocks (29%) and public roads (16%). In 9% of the cases, the accident occurred as a direct result of the horse's behavior. Ball et al investigated 78 adult patients who were admitted to the Foothills Medical Centre, Alberta, Canada, for equestrian injuries between 1995 and 2005.[59,60] The horses were on average 7 years of age. The accident was caused due to the horse being "spooked" in 35% of cases, not being fully trained for the rider's commands in 27% of the cases, and having a bad temperament in 15% of the accident scenarios. Similarly, Thompson and von Hollen reported that 70.3% of accidents were considered to be the horse's fault, with 26.9% of all cases resulting from the horse being "spooked."[55] Dekker et al investigated 100 pediatric cases of hospitalized horse-related injuries and reported that the accident was as a direct result of the horse or pony taking fright from people, noises, or traffic in 78% of cases.[61]

In Colorado, USA, Newton and Nielson reviewed the hospital medical records of 85 patients presenting to the emergency department of a southwestern Colorado hospital.[53] It was thought that 38% of the injuries sustained during the study period were preventable. This conclusion was drawn from participant statements, noting their own carelessness or a mismatch between the horse and the ability of the rider. A total of 68% of patients were riding or tending a rental horse. Kiss et al retrospectively investigated pediatric horse-related injuries between 1999 and 2003.[62] The results suggested that children who suffered an accident with their own or a familiar horse had an average hospital stay of 2.88 days, while those whose injury originated from having ridden or contacted an unknown horse had an average length of hospital treatment of 7.33 days ($p<0.046$, ANOVA). For those children who lived in families which owned a horse, they were more likely to be injured during handling the horse than those who did not own a horse. However, the number of injuries that had occurred while riding a horse was significantly higher among children who did not possess a horse ($p<0.041$, 'G–K tau'). These studies indicate that inappropriate matching of rider skill and horse influences the injury outcome and risks.

Injury Characteristics

Injury mechanism. Of the 39 manuscripts which examined the overall spread of injury mechanisms, 38 stated that a fall from horseback was the most frequently observed injury mechanism. The proportion of falls ranged from 42.7% to 82% of all injury mechanisms.[19,63] Furthermore, falls were the most common type of mechanism related to spinal injuries and maxillofacial injuries.[23,58,64] Iba et al, which did not correspond with other reports, observed falls to be the second most common injury

mechanism and focused on horse-handling injuries among stable workers in Japan, where participants were mostly involved in unmounted activities.[36] Kicks were also frequently observed and were noted as the second most frequent injury mechanisms in 23 of the 42 studies. Other mechanisms noted to occur were being crushed or rolled on, being trodden on or trampled, and being bitten.[12,15-17,23,26,28,31,36,43,48,51,53,59,65-69] Crushing was the most common type of mechanism for both foot lesions and pelvic fractures.[54,70]

Type of injury. There were 58 studies which investigated all injuries to those both mounted and unmounted. The most frequently noted types of injuries were fractures but also frequently observed were concussions and soft tissue injuries such as contusions, abrasions. and lacerations. Of the 58 studies, 23 found that injuries to the head occurred most frequently and were seen in up to 55% of all riders.[66] A further 15 of the 58 studies found the upper limb to be the most frequently injured and four stated that the truncal region suffered the most injuries.

Mounted compared to unmounted riders were investigated by Carmichael et al in a total of 284 horse-related accidents in Kentucky, USA (retrospectively examined).[40] The results suggested that facial and abdominal injuries were more common among unmounted equestrians ($p<0.01$, $p<0.01$, respectively), and chest and leg injuries were more common in the mounted group ($p=0.03$, $p<0.01$, respectively). However, the rate of head injury was not different between mounted and unmounted equestrians. Lloyd discovered that of 237 patients injured from horse-related causes, 50% suffered a head injury.[49] It was reported that 80% of these head injuries were caused from a fall from horseback, and 15% were due to a kick from a horse.

When specifically investigating injuries due to a fall from horseback, musculoskeletal injuries were found to be the most frequently occurring injury.[26] However, reports on the most common injury location have been conflicting. Thomas et al retrospectively investigated 102,904 horse-related accidents in the United States and reported that in falls, the most common injury location was the head/neck or trunk (63.9%), with the most common principal diagnoses being fractures (28.0%) and contusions/abrasions (27.9%).[47] Contrastingly, Danielsson and Westlin and Smartt and Chalmers both reported that falls most frequently caused injuries to the limbs.[16,41] Danielsson and Westlin specifically noted injuries to the upper limbs, which consisted mostly of fractures caused by indirect violence when extending the arm. Smartt and Chalmers investigated 716 horse-related accidents in New Zealand and found that over half of the falls resulted in fractures and dislocations of the limb and girdle bones (171 cases, 58%) or the skull, spine, and pelvic bones (123 cases, 42%).[16] For a fall combined with a secondary mechanism, most injuries sustained were to the limbs and girdles (14/31 cases, 45%). An additional 23% of falls resulted in internal injuries, including intracranial injury (82 cases, 76%), injury to the spleen (15 cases, 12%), injury to the kidney (8 cases, 7%), traumatic pneumothorax (11 cases, 8%) and injury to the cranial and spinal nerves (3 cases, 2%).

Reports regarding unmounted patients have shown conflicting results and may be due to the variety of different mechanisms and tasks being conducted. Thomas reported for unmounted patients mechanisms were being struck (56.6%) or crushed (25.6%); the most common principal diagnoses were contusions/abrasions (40.8%) and fractures (18.9%).[47] A majority (60.2%) of injuries for those not mounted involved the extremities. However, Smartt and Chalmers suggested that incidents to horse handlers/bystanders resulted in dislocations or fractures (80 cases, 52%); internal injury (33 cases, 22%); open or superficial wounds (29 cases, 19%); “other and unspecified” injuries to the head, neck, and trunk (6 cases, 4%); and traumatic amputation or crushing injury (5 cases, 3%).[16]

Horse kicks to an unmounted equestrian typically resulted in facial injuries, including severe facial and head trauma, but have also been seen to cause significant chest and abdominal injuries.[41,42,51] Weber et al found that of all the injuries associated with kicks in the sample of 679 horse-related accidents, orbital fractures were the most common followed by multiple rib fractures, liver injuries, head trauma (e.g., basilar skull and skull fractures), and LeFort type midface fractures.[51] In contrast, a kick by another horse to a mounted equestrian resulted most frequently in lower leg injuries.[41] Regardless, Ueeck et al reported that maxilla-facial injuries due to a horse kick resulted in a more serious injury than other mechanisms ($p=0.048$) and accounted for 13 of 18 fractures.[23]

Danielsson and Westlin investigated injuries associated with bites and tramples and discovered that horse bites tended to cause small bruises and scratches of the skin, severe enough in only one case to require suturing.[41] Trampling was associated with contusions (n=11), sores (n=1), and fractures of the wrists and toes.

Weber et al reported that the mechanism of being crushed by the horse had the highest risk for pelvic ring (32.4%) and abdominal injuries (35.2%).[51] In contrast, accidents while driving a carriage typically caused severe chest injuries (63.3%) as well as pelvic and extremity fractures, resulting in significant injury severity (ISS 20.7, SD 10.6). Furthermore, falls and carriage-related mechanisms were also associated with intracranial hemorrhage.

In 2008, Kiss et al investigated the factors effecting horseback riding and horse care injuries to children.[62] Children injured on the upper extremities and the shoulder were significantly younger than those with other injury localisation (mean age: 10.5 vs. 12.3 years, $p<0.004$, ANOVA). Patients who had an injury on the head/neck and the lower extremities were significantly older than those with other injury localisation (mean age: 12.7 vs. 10.9 years, $p<0.015$, 'A'). The severity of injuries was found to increase slightly with age, peaking at 16 to 18 years. Abu-Kishk et al also investigated differences in injury type by age.[12] This study investigated both adult and child horse-related injuries. Similarly, older patients were more likely to suffer from fractures and neck trauma than were pediatric patients ($p=0.034$ and $p=0.019$ respectively).

Long-term consequences. A substantial proportion of equestrians experience long-term consequences following horse-related accidents. In 1998, Frankel et al established a method for investigation on long-term consequences of horse-related accidents (retrospective data and surveys).[71] In this investigation, 92 cases were reviewed, with 19% reporting disability and 3% having stopped riding because of the injury. Most disability was due to chronic pain and arthritis. This method was also adopted by Dekker et al in the Netherland in 2004.[61] Of the 100 respondents, 41% stated that they still experienced physical or psychosocial complaints as a result of the injury at the time of the interview (up to four years post-accident), and 39% still experienced absenteeism from school with mean absenteeism time being 2 weeks. A further 29% could not participate in horse riding any longer. Lim et al also used patient interviews to investigate long-term effects of injury.[50] At one month, 13% of professional and 19% of recreational equestrians were still disabled, and at six months, 1% of professional and 2% of recreational equestrians were still disabled.

In 2014, Papachristos et al reviewed the long-term outcome of adults (>17 years of age) presenting to hospitals for any horse-related injury.[45] Of the 172 cases, there were 124 questionnaire respondents. Of these respondents, 31% reported that they still experienced pain from the injury. The largest proportion of ongoing moderate or severe pain was seen in the youngest age group (18 to 35 years) and the oldest age group (>45 years). There were 15 equestrians who had not returned to work.

Ball et al conducted a retrospective review of patients presenting to a level one trauma registry (1995–2005) in Canada with a horse-related injury.[59] A patient survey was conducted in conjunction with the retrospective review to describe the functional outcomes of the equestrians. Of the 151 patients presenting to the hospital within the study timeframe, 78 patients completed the survey. Thirty-seven (55%) respondents had chronic physical difficulties because of the accident (50% of all males; 59% of all females). Seventy-six percent (28/37) of residual functional deficits were orthopedic related. Thirty-five percent (13/37) involved upper extremities, including pain and/or weakness in patients' hands, wrists, or shoulders. Chronic pain or headaches were identified in 23 (62%) patients. Forty-one percent of respondents explicitly described functional disabilities involving decreased balance or limited use of hands and arms, including an inability to lift. In patients with head injuries, cognitive impairments included decreased memory, mood changes, and personality changes. Although 55% of respondents reported chronic physical difficulties, the majority (87%) were still riding at the time of the survey. Forty-six percent (31/67) did admit to changing their riding practices as a result of the injury. McCrory et al presented a case of a professional jockey who had suffered 10 to 12 admissions to hospital for concussion from the age of 16.[72] As a result, the rider suffered slow processing speeds, slow reaction time, and impaired short-term memory.

Balendra et al reported on career-ending injuries to professional jockeys through investigating Professional Riders Insurance Schemes notes.[73] Of the 45 participants, the career-ending injuries primarily involved fractures (43%) and neurological pathological injuries (21%), with the most common body regions injured being the upper limbs (22.1%), head (20%), and lower limbs (17.7%).

Guyton et al used a validated survey form to observe physical, social, and role dysfunction caused by health problems from horse-related injuries and compared the results to two general population cohorts.[31] Ninety-one patients participated and compared to the population cohorts, the subjects suffered diminution in their ability to perform usual daily activities associated with physical problems, diminution in "social function," and higher "bodily pain." In the pediatric setting, Kiss et al discovered that of the 112 children, almost one-third suffered long-term physical (30.4%) and psychological (28.65%) disabilities following the accident.[62] Of the physical disabilities, most reported disturbing scars and consistent pain. Psychological disabilities consisted mostly of an on-going fear of horses (13%) and "flashbacks" (14%).

Siebegna et al investigated horse-related spinal injuries. Of the 32 cases investigated, 22% of patients suffered permanent occupational disabilities.[21] Lin et al discovered that in a sample of 121 equestrians who had sustained a spinal cord injury from a horseback riding accident, the injuries most commonly resulted in incomplete tetraplegia (41%) followed by complete paraplegia (24%).[74] Triantafyllopoulus et al presented three cases of spinal injury due to horse-riding accidents.[75] All three patients sustained

fracture at the levels of T5–T8. One patient fully recovered after surgery. Two patients remained paraplegic despite early surgical treatment and prolonged rehabilitation therapy.

Characteristics of fatalities. Neurological trauma has been reported to be the most common cause of death in horse-related accidents.[5,44,68,76,77] Davidson et al retrospectively examined 10 years of injury data in Michigan, USA.[78] Out of the 90 cases investigated, there were six mortalities. Extensive head injury was found to be the cause of death in all six mortalities; two patients sustained kicks by the horse, and four fell from the horse. Of the 284 horse-related injuries investigated by Carmichael et al, there were three deaths, two of which were due to severe head injury from a kick and the other a head injury after fall from a trailer while loading a horse.[40] All fatalities occurred while the equestrian was unmounted.

Another common injury resulting in equestrian fatalities is abdominal injury. Clarke et al reported a mortality rate of 7% (n=5).[67] Four of these fatalities resulted from head trauma while one was caused by blunt abdominal trauma with injuries to the liver and spleen. Of the four fatalities in the sample of professional jockeys with career-ending injuries reported on by Balendra et al, two died as a direct result of head injuries.[73] The other two jockeys suffered injuries to their torso that resulted in intra-thoracic and intra-abdominal hemorrhage. Additionally, in the findings reported by Guyton et al, out of the three fatalities, two were the result of intracranial hemorrhage -- neither was wearing a helmet.[31] The third fatality was helmeted and died of hemorrhagic shock after a pelvic fracture.

Theodore et al reported on three deaths during their study period retrospectively investigating pediatric horse-related injury in Australia. All adolescents had adult supervision at the time of the incident.[38] One (33.3%) adolescent, without a helmet, presented to the ED with complete transection of the descending thoracic aorta and was declared deceased. Two (66.7%) adolescents, one with and the other without a helmet, were admitted to hospital with severe traumatic brain injury and later died. Two of the deaths were in females, one in males, and all aged 15 to 16 years.

As with all injuries, fatal injuries are commonly reported to occur most frequently in females.[6] In 1993, Buckley et al investigated 54 horse-related fatalities in New Zealand between 1977 and 1986.[5] The overall death rate was found to be 0.17 per 100,000 persons per year. The death rate for males was 0.15, and for females, 0.19. Amongst the 38 fatalities retrospectively examined by Aronson and Tough between 1975 and 1990 in Alberta, Canada, 17 were female and 20 were adults.[79] Of the mounted riders, 17 suffered head injury and 8 truncal injury, and of those unmounted, five (38%) died from a head injury and eight from truncal injuries. Only one rider wore helmet. A substantial proportion (65.8%) involved the rider falling from horse or the horse falling and subsequently crushing the rider.

The injury mechanisms leading to fatal horse-related accidents appear to be far reaching. Cripps et al reported that while 92% of the fatalities investigated occurred during horse-riding accidents, 8% were caused by motor vehicle accidents involving a collision with horse riders or horse-drawn vehicles or during animal-drawn vehicle accidents.[29] Williams and Ashby also reported on the mechanisms involved in horse-related fatalities, discovering that out of the 17 fatal cases investigated, 10 occurred while riding, two fell from the horse, two hit an object, one was hit by a car, and one was crushed.[48] Two occurred as a direct result of equipment failure and one rider was dragged along behind the horse for a substantial period. Of those unmounted, three were kicked, two occurred in traffic accidents, and two were trampled by the horse. In a study by Weber et al, mortality rate was found to be higher (14.8%) in drivers of carriages than in those who fell from horseback (4.7%), were kicked (3.5%), and crushed (4%).[51] However, based on the limited data available, in cross-country specific accidents, fatalities exclusively occurred when the horse fell on the rider, such as when the horse “cartwheeled” over a jump.[7,80]

Prevention and Safety Promotion

Protective clothing has been developed for the horse-riding setting including helmets and protective vests, and some benefit for this protection has been found. However, there is a need to examine the level of protection afforded by these garments and where improvements in designs can be made. Current work is limited by the amount of information on the protective clothing worn by the horse-riders at the time of the accident, including specifics on type of helmet and material properties. Additionally, small response rates and use of retrospective data, with the inability to follow up on this information, make it difficult to draw clear conclusions.

Helmets. Helmets have been developed to provide some form of protection to equestrians. The benefit of wearing a helmet has been reported in several investigations. Abu-Zidan et al reported that patients wearing helmets displayed significantly less incidence of intracranial injuries.[44] Bilaniuk et al found that the mean injury severity score was significantly lower in the group of riders who wore a helmet than those who did not.[32] When investigating hospital admission, Cuenca et al discovered that patients who were not wearing a helmet were significantly more likely to require hospital admission (64% vs. 39%), and Lim et al found that professional riders were more likely to wear a helmet and less likely to be admitted to hospital.[50,63] Hasler et al reported that helmet

usage was linked to a 50% reduction in risk of being in an injurious horse riding accident.[43] Additionally, in 2017, Theodore et al reported that helmet usage was significantly associated with a length of stay in hospital of less than 24 hours.[38]

Chitnavis et al set out to investigate how the pattern of equestrian injury changed over the span of 20 years.[28] Data from 1991 were prospectively collected and compared to results collected in 1971 at the same hospital. A five-fold decrease in the number of patients admitted to hospital with head injuries was reported. Chitnavis et al suggested that this could be linked to helmet use, with usage rates increasing from an estimated 42% to 72/73%.[28] However, there was no statistical analysis and limited information on helmet use available.

Despite the benefits of helmets and increase in helmet usage, head injury rates are still high. One reason to explain this may be the differing reported rates of helmet usage around the world, with figures being reported as low as 34% in the USA in 2013 and as high as 72% in Australia in 2017.[31,38] However, it may also be that helmets do not currently provide sufficient protection to avoid head injuries in many equestrian accidents. Notably, in 2000, Waller et al presented a cross-section investigation on injury rates in professional jockeys.[69] Despite helmet usage being mandatory for jockeys, head injury was still found to be the most frequently occurring injury.

It is known from other areas that helmets are a key factor for head injury reduction. For example, a study by Ekman and Ekman described some of the results of a long-term bicycle helmet campaign for children in a Swedish district, where helmet use increased from 5 to 64% among children up to age 15 and an astonishing reduction of hospitalization resulting in head injuries was seen.[81] This indicates that perhaps helmets do not act sufficiently in the equestrian setting. One suggestion is that the energy absorption provided in helmets is designed for harder surfaces such as roadways and not for contact with softer grass or sand surfaces. Clark et al collected helmets from insurance companies which had been worn by riders involved in accidents in order to assess the influence of the impact surface on helmet damage.[82] Helmets (n=20) were examined for signs of damage to the external and internal components. In this preliminary study, of the 20 helmets examined, four involved impacts on a road and 16 on turf. Half of the impacts on a road and 14 of the turf impacts resulted in a concussion. Overall, all helmets involved in impacts with the road suffered some sort of damage. No damage was observed in 35% of the turf cases, and five of these seven suffered a head injury. Impacts on a road were found to have significantly higher residual crush of the helmet liner compared to impact on turf. The results seemed to suggest that the helmets absorbed insufficient energy to prevent head injury in riders who impacted turf. This finding was supported by the work of Bourdet and Willinger who found that 40% of head impacts in professional horse racing occur below the test line for equestrian helmet standards.[83]

Another suggestion is that current helmet designs conform to a standard which determines helmet performance solely on linear acceleration without examining angular kinematics. Rueda et al utilized finite element modelling (FEM) to create a realistic helmet model.[84] While linear acceleration was seen to have a low correlation with the stress and strain in the brain, angular acceleration displayed good correlation and encompassed the sensitivity of the human head to impacts in different directions. This indicates that angular acceleration is important to consider when the actual injury mechanisms of human brain tissue are considered.

Additionally, it has been shown that injuries to the head and face occur as frequently to those equestrians who are unmounted as those who are mounted.[40] Eckert et al reported a high number of hoof kick injuries to the face during horse care, and as helmets are not typically used by unmounted equestrians, there could be large proportion of head injuries occurring while equestrians are unmounted.[52]

Other protection. Protective vests and more recently, inflatable vests, have been developed as another protective device for horse riders. However, protective vests have received little attention, and they are worn by only a small number of equestrians. Kiss et al found that only four of the 112 accident-involved equestrians they interviewed were wearing a vest at the time the accident occurred.[62] In 2007, Mayberry et al reported this figure to be 7% of all respondents to a cross-sectional survey.[57] In eventing, the use of equestrian vests is higher, with Whitlock finding that all of the riders wore body protectors in eventing competitions in the UK between 1992 and 1997.[80] None of the riders with a shoulder injury were wearing a shoulder protector, while 20 riders who fell while wearing a shoulder protector did not sustain a severe injury.

A small number of studies were found which examined the injury reduction benefits of protective vests. Hynd et al performed physical testing on vests and airbag vests where an equine cadaver was dropped onto an instrumented Hybrid III ATD.[85] The test was performed when the dummy was wearing only a standard airbag and when the dummy was wearing both the standard vest and an airbag vest. When the dummy wore both, the peak chest force recorded was 4.5kN and the chest deflection was 66mm. This corresponded to an 81% risk of severe injury. While still high, this was a much better outcome than when the dummy wore only a standard vest with a peak force of 7kN, chest deflection of 77mm and 94% risk of severe injury.

In 2016, Brolin and Wass performed human body modelling to assess the performance of equestrian vests under different scenarios.[86] When the model simulated being trampled by a horse, the risk of injury was higher for hoof impacts close to the sternum compared to more lateral locations that had up to 25% less risk. The safety-vest provided protection against horse kicks, with the chest withstanding 125 to 175Ns compared to no vest 225Ns. However, the vest provided no protection under rotational falls when the horse landed on top of the rider.

Foote et al investigated insurance claims and video footage of riders involved in horse racing competitions in NSW and Victoria, Australia.[87] In the years following the introduction of vests, there was a significant reduction in the number of insurance claims per event starters (0.15% vs. 0.1%) in Victoria, but this was not seen in NSW. There was a reduction in the number of days absent from work following the injury, but this was not significant (115 vs. 99 average days). There was no difference in the distribution of injury, but there was a significant reduction in sprain injuries. There appeared to be a significant increase in neck injuries, but upon examination of video footage, these were mostly indirect injuries and when the rider fell head first onto the track.

The role of appropriate tack was noted by two of the studies in this literature review. Of the 85 horse-related accidents investigated by Newton et al loose cinches and leather were blamed by the participants during follow up interviews to be the cause of the injury in 25% of the cases.[53] A further 10% were a result of their shoe remaining stuck in the stirrup, and 10% were because of non-secure stirrups. Thomas et al found that of 102,904 persons injured due to horse-related causes between 2001 and 2003 in the USA, 350 were injured each year when their foot got caught in the stirrup, 550 were injured when the saddle slipped or broke, and 2000 were injured annually when their hands or fingers were caught in the horses' tack.[47] These studies highlighted the importance of maintaining of tack appropriately as well as using protective gloves and safety stirrups which are designed to release the rider's foot as they fall from the horse. However, there were no found reports which investigated the injury reduction of these measures.

Face protectors are safety devices which have been developed specifically for polo players. However, the one study the literature search returned reported usage rates to be low. This study by Costa-Paz et al prospectively investigated 34 polo riders during the 1996 season.[88] Only two players wore a face protector, and face lacerations occurred 46 times over the season.

Gass et al conducted a cross-sectional survey to investigate dental injuries in showjumping and the use of specially designed mouth guards for riders.[89] Altogether, 15% of respondents experienced tooth injuries, mostly fractures (57.1%) and dislocations (18.4%). A majority of respondents (71.7%) knew a mouthguard for showjumping exists, but only three owned one and none used these mouthguards.

Risk Factors

There has been a scarcity of investigations which have attempted to reach beyond initial descriptive statistics to discover the risk factors associated with horse-related accidents using statistical modelling techniques. Only two of these manuscripts utilized a cross-sectional methodology and could investigate the actual risk of being involved in a horse-related accident. The others used either a retrospective sample of accidents to measure factors influencing the severity of an injury or disability. One manuscript used a case-control survey on a convenience-based sample of horse-related injuries, but the control group was a random sample of non-injured horse riders and were not matched to cases. With the multiple different outcomes measured, it is difficult to find consistent findings on one measure; however, age, experience and mechanism appeared to be consistent themes throughout these investigations.

Prospective and retrospective cohort investigations. The first found investigation was by Abu-Zidan and Rao in 2003.[44] This investigation aimed to define the factors that affect the injury severity score (ISS) and duration of the hospital stay following horse-related injuries. To address the study aims, a prospective investigation of 231 patients who presented to the Royal Perth Hospital between 1994 and 2000 was conducted. A generalized linear model was used to test for the effects of age, sex, cause of injury, number of mechanisms involved in the injury, year, place of injury, and profession of the injured on ISS and length of hospital stay. The significant factors that affected hospital stay were the primary cause of injury, with suffering a blow by a horse leading to the longest stay in hospital, and the number of mechanisms of injury, with those having three mechanisms having longer hospital duration than those with one or two mechanisms. None of the studied variables affected the ISS.

Loder also analyzed predictors of serious injury, being admission to hospital, in a retrospective sample of horse-related accidents (n = 5,033).[30] This sample included all patients who were presented to an emergency department of a hospital in the USA between 2002 and 2004. Stepwise logistic regression analysis revealed that age older than 18 years, suffering a fracture, a traumatic brain injury, or the accident occurring on public property were predictive of hospital admission.

Dekker et al set out to investigate the factors for possible development of long-term disabilities arising from pediatric equestrian injuries.[61] Patients who were 17 years or younger who had presented to the emergency department of the University Hospital Groningen, the Netherlands, between January 1995 and August 2000, were investigated retrospectively. Patients were contacted and asked to complete an interview and a Child Health Questionnaire-Child Form (CHQCF87) regarding their injuries and residual long-term health outcomes. From logistic regression, it appeared that the odds of an unfavorable outcome for advanced riders were 2.6 times higher than for novice riders, and for those with a fracture to the head or torso the odds of an unfavorable outcome were 3.3 times higher than for those with extremity fractures. Finally, those patients who sustained subsequent injuries in the period after the horse-riding accident were 2.8 times more to suffer a disability than those who did not.

Cross-sectional studies. Bethune conducted a web-based, cross-sectional survey of equestrians in Maryland and Virginia, USA, with the overarching goal of identifying risk associated with suffering a horse-related accident which led to injury.[90] A total of 908 survey responses were collected between July and September 2010. Information collected included socio-demographic variables, equine interaction characteristics, and use of safety measures. The odds of being injured within the past 12 months for adults age 65 and older were significantly lower than for adults age 18 to 24 (OR=0.42, 95%CI=0.19 to 0.96). When looking at years of experience, the odds of injury within the past 12 months for adults with 15 or more years of experience were significantly lower than for adults with 1 to 15 years of experience (OR=0.55, 95% CI=0.39 to 0.77). Logistic regression was also used to investigate a rider having ever suffered an injury, but the results were contradictory, possibly as the rider characteristics were based on their current details, not when the accident occurred.

Ekberg et al also used a cross-sectional survey to examine risk-factors associated with injuries to adult Swedish eventing athletes in 2007.[91] Variables investigated included age, sex, risk-taking attitude, and qualification level. However, only the personal attitude to risk-taking was found to contribute to sustaining an injury event during the study season. Level of qualification was associated with injury events per 1,000 hours exposure to eventing practice and competition for each individual, yet this was found for overuse injuries only.

Case-control studies. In 2011, Hasler et al conducted a case-control study to analyze the risk factors associated with horse riding.[43] A survey was prospectively conducted on 61 injured equestrians (16 years or older) who presented to an emergency department in Switzerland between July and December 2008. The control group included 102 non-injured equestrians. The variables included as potential risk factors were equestrian and horse characteristics as well as the use of protective equipment. From logistic regression, riders were more likely to be in the control group if they held a diploma in horse riding ($p = 0.004$), were of an older age ($p = 0.015$), or were of male gender ($p = 0.04$). In the racing industry, a series of studies was conducted by Hitchens et al in 2011 and 2012 investigating the factors associated with jockey falls.[92-94] The first in this series of studies was the only to report on predictors of injurious falls. Data were collected from reports of falls provided by the Principal Racing Authority from each state in Australia between 2002 and 2006 and included information on jockey conditions, horse conditions, race conditions, and weather ad track conditions. The Poisson regression model was used to estimate incidence rate ratios, including those variables which significantly predicted falls in univariable models. Factors associated with falls were female sex of jockey (IRR=1.11; 95% CI=1.00-1.23), being an apprentice jockey (IRR=1.51; 95% CI=1.39 to 1.63), being an amateur jockey (IRR=1.44; 95% CI=1.11 to 1.86), drier track rating ($p<0.001$), younger horse age ($p<0.001$), shorter race distance ($p<0.001$), lower field size ($p<0.013$), and lower race grade ($p<0.001$). Significant predictors of injurious falls were apprentice jockey (IRR=1.24; 95% CI =.06 to 1.45), drier track rating ($p=0.002$), younger horse age ($p<0.001$), shorter race distance ($p=0.024$), and lower race grade ($p<0.001$).

CONCLUSIONS

Horse-related injuries present a major public health concern. A review of the literature found that horse-related injuries most frequently involve young females who have fallen from horseback. However, it has also been shown that older men are also at risk of these injuries, despite the overall numbers being small. While type of injury varied with the injury mechanism, head injuries were found by all relevant studies to be the most common cause of fatality, yet none of the studies examined predictors of fatalities. Head injuries were also frequently occurring in non-fatal cases and were due to not only falls from horseback, but also being kicked in the head. The introduction of helmets has reduced the incidence of head injury, yet head injury rates are still high, indicating a need for further improvement and development of safety devices.

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