Equestrian fall characteristics – Rider head impacts during hunter/jumper competitions

Stephanie Bonin, Karin Brolin, Madelen Fahlstedt

I. INTRODUCTION

Rider falls during equestrian activities can result in concussions, most often reported in racing-type disciplines [1]. The head impact velocity of a rider falling from a horse depends on the rider's initial head height, horizontal speed, pre-impact body rotation, and interaction with the horse during the fall. Head impact speeds for equestrian falls have been reported to be between 6 m/s and 16 m/s at an angle of 10° to 64° relative to horizontal during steeplechase and flat-racing falls [2]. However, similar data for the hunter/jumper discipline, which is popular in the United States, are limited. Therefore, we sought to estimate rider head impact velocity resulting from falls associated with concussions during hunter/jumper disciplines reported at the United States Equestrian Federation (USEF) sanctioned competitions. These results can help inform helmet certification standards organisations on head impact characteristics associated with concussions from equestrian-related falls.

II. METHODS

Anonymised data from 2010 to 2021 were provided by the USEF. The database tabulates standardised reports from licensed officials regarding injury-producing incidents that occurred during USEF competitions. The data were classified according to event type and included the following: hunter, jumper, hunter/jumper, hunter seat equitation, and medal classes. Only cases identified as a fall from a horse with a possible head injury were included. Falls were classified by the rider's fall direction and, for cases involving jumping, where the fall happened relative to a jump. The horse's gait was either provided or interpreted based on the fall description. For example, a fall that occurred between fences while jumping a course was interpreted as happening while the horse was cantering. Videos were not available, so we estimated head impact speed and angle based on knowledge of the likely rider head height from the ground and typical canter speeds.

A rider was classified as concussed if described as having loss of consciousness, memory loss, repetitive questioning, disorientation, blurry vision, nausea, or ataxia. A rider was classified as possibly concussed if described as feeling dizzy or sleepy or as possibly having a concussion. A rider was identified as not concussed if described as only having head pain or being alert and oriented to person, place, and time and with no other symptoms listed. The surface condition was described as dirt, sand, synthetic, or grass.

III. INITIAL FINDINGS

The database included 9,357 total entries, 5,869 (63%) were classified as hunter/jumper. Within the hunter/jumper cases, there were 1,681 (29%) falls from a horse that comprised the dataset for this study. Within the 1,681 falls, 94% of the riders were female and 55% were ≥18 years old. Most riders (95%) were wearing an ASTM/SEI approved helmet. The rider's fall direction relative to the horse was reported for 32% of falls, with the forward direction being more common (54%) than sideways (38%), backwards (4%), or being projected upwards (4%) (Fig 1a). Surface conditions were 71% sand/dirt/artificial, 12% grass, and 3% were undefined.

Riders' head-related symptoms were reported for 1,324/1,681 (79%) of falls, of which 1,003 cases reported possible or positive signs of concussion (Fig 1b). Within this subset, the horse's gait or movement at the time of the fall was either provided or interpreted based on the fall description for 782/1,003 (78%) cases. A total of 746/1,003 (74%) falls with possible or positive concussion signs happened while at a canter or gallop (as stated + interpreted) (Fig 1c).

S. Bonin (e-mail: stephanie.bonin@meaforensic.com, tel: +1 949 855 4632) is a Senior Engineer at MEA Forensic Engineers & Scientists, Laguna Hills, CA, USA. K. Brolin is a consultant with Lightness by Design Stockholm, Sweden. M. Fahlstedt is Biomechanical Specialist at Mips AB, Täby, Sweden.

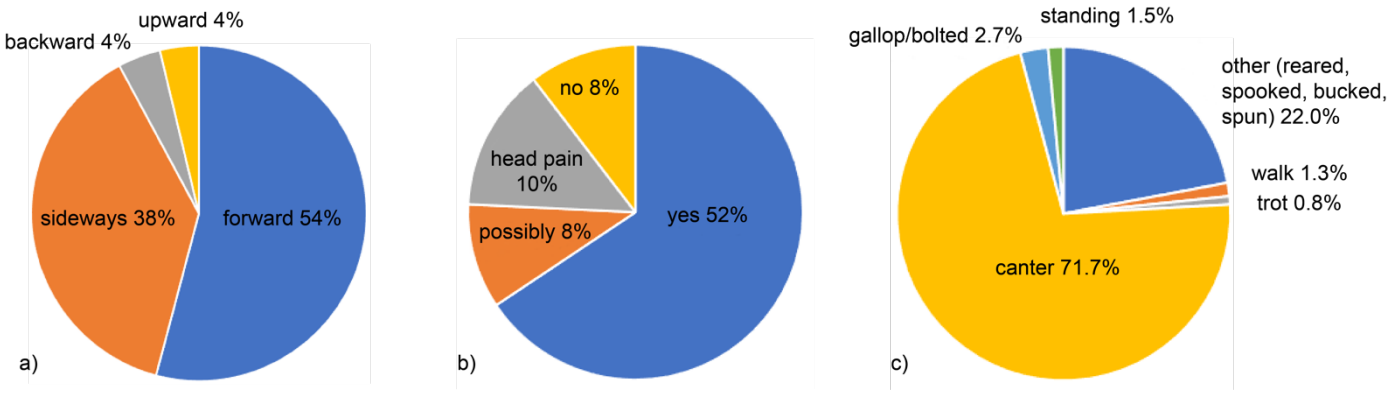

Fig 1: a) 534/1,681 (32%) of cases reported rider's fall direction, b) 1,324/1,681 (79%) of cases reported head-related symptoms with possible or positive signs of concussion for 60%, c) 782/1,003 (78%) of cases with positive or possible concussion had information about the horse's gait.

IV. DISCUSSION

We sought to estimate rider head impact velocity resulting from falls associated with concussions during hunter/jumper disciplines at USEF competitions. The vertical component of rider head impact speed was estimated as 6.2 m/s to 6.7 m/s by considering a range of horse heights (14.2 hands to 17.2 hands high or 1.4 m to 1.7 m) and the pelvis to head CoG distance for an average female (0.6 m). The horizontal component was estimated based on typical speeds for the horse's gait at the time of the fall. During hunter/jumper disciplines, horses canter at about 4 m/s to 7 m/s [3]. Relying on these vertical and horizontal speed estimates, the riders experienced an oblique head impact at 7.4 m/s to 9.7 m/s at angle of 42° to 60° relative to the ground during an unobstructed fall.

As most falls happened while the horse was cantering or galloping (74% as stated and interpreted), most riders with concussion symptoms likely sustained oblique head impacts. Oblique impacts generate rotational head kinematics associated with brain strain and therefore concussions [4, 5].

Our study is limited by the available descriptions of the horses' gait and riders' fall description and symptoms. Rider interactions with the horse that slowed the rider prior to impact, or riders projected higher than their initial position are not captured. In addition, 14% of gaits classified as a canter happened when the horse refused a jump or darted sideways in front of a jump but were interpreted as occurring at a canter, which may be an overestimate of the horses' speed at the time of the fall. Nonetheless, our estimated range of head impact speed and angle are within the range of prior studies that quantified head impact velocity of concussed jockeys and eventing riders from video analysis (Table I, [2]).

Table I: Resultant head impact speed (m/s) and angle (°) for concussed riders from [2] and estimated for hunter/jumper riders from the current data (shaded).

	Resultant head impact speed (m/s)			Head impact angle (°)		
	Min.	Max.	Mean (SD)	Min.	Max.	Mean (SD)
Eventing	6.7	7.5	7.1 (0.5)	34	47	41 (9)
Flat racing	10.0	15.2	12.5 (2.0)	13	47	22 (13)
Steeplechase	6.3	16.2	9.7 (2.6)	10	64	29 (14)
Hunter/jumper estimate	7.4	9.7		42	60	

Current equestrian helmet certification standards do not include oblique impact tests. Our results suggest that a horizontal velocity component is likely present during most falls associated with a concussion during hunter/jumper competitions and thus equestrian helmet testing should include oblique impacts when evaluating helmet performance. Certification testing uses rigid impacting surfaces whereas 71% of the falls happened on compliant surfaces such as sand, dirt, and artificial footing. Additional work is needed to understand how the shear response of complaint surfaces affects the head and helmet responses and how to incorporate this effect into repeatable laboratory testing.

V. REFERENCES

[1] Zuckerman, World Neurosurg, 2014 [2] Clark, J Sci Med Sport, 2020 [3] Clayton, Equine Exercise Sci, 1991
[4] Kleiven, Stapp, 2007 [5] Zhang, J Biomech Eng, 2004