# THE EFFECTIVENESS OF SAFETY EQUIPMENT IN HORSE RACING FALLS.

**T. Gibson[1], K. Thai[2], J. Saxon[3] and R. Pollock[4]**

**[1]Human Impact Engineering, Sydney, [2]UNSW (formerly Human Impact Engineering), [3]Consultant, Sydney, and [4]Harness Racing Australia.**

## ABSTRACT
The effectiveness of the personal protective equipment PPE used by jockeys and harness drivers in falls during racing was investigated. In Australia the wearing of helmets and protective vests is mandatory in both forms of the sport, though the equipment standards differ. The incidence of injury was analysed and the mechanisms of injury investigated by video analysis of actual injury incidents. The effectiveness of the safety equipment was assessed through physical testing. The differing injury mechanisms and track surfaces in the two sports result in unique requirements for the protective equipment used. The needs for future development of improved equestrian personal protective equipment are outlined.

**Keywords**
FALL ACCIDENTS, ACCIDENT RECONSTRUCTIONS, PROTECTION, SPORT ACCIDENTS

**THIS** paper combines the results of two studies investigating the effectiveness of personal protective equipment (PPE) used by thoroughbred jockeys and harness drivers in racing falls. In Australia the compulsory wearing of both helmets and protective vests has been in place in both sports for the last decade. The standards used for the equipment are different and little research has been published regarding the effectiveness of the equipment used. The aim of this paper is to present new information regarding the incidence and mechanisms of injury to participants as a guide to the development of improved equestrian PPE standards.

## METHODOLOGY
The injury incidence data was collected for the participants in these two forms of horse racing, Gibson and Thai (2007) and Saxon et al. (2006). The first stage was to collate the data in the racing incident reports recorded by the course officials during official race meetings, collected by the Harness Racing Australia (HRA) and the Australian Racing Board (ARB). This analysis was extended to the investigation of the insurance claims for injury to the participants.

The injury mechanisms in the racing falls was investigated from available videos of the race incidents. The video footage of the falls was obtained from the course officials of the HRA and ARB and from broadcast footage of the events. Approximately 20 falls from each form of racing were collected, some with multiple views. Each case video was converted into discrete frames and the frame by frame video footage analysed to obtain estimates of the fall velocity and height, the nature of the object or surface impacted and the participant's fall posture and impacted body regions.

Physical tests were made to measure the impact characteristics of the track surfaces and the protective capabilities of the equipment. These tests used current biomechanical test methodology in the form of the THOR advanced dummy biofidelic head and chest forms, GESAC (2001). Testing included on-site drop testing to obtain the characteristics of the track surfaces and in laboratory testing of some typical PPE, including helmets and protective vests.

## RESULTS
Harness racing in Australia in the period from 2000 to 2005 had reported 324 injuries to 255 drivers, Gibson and Thai (2007). The most common injuries were to upper and lower limbs (17.3% and 14.8% respectively), shoulder and clavicle (13.9%), to chest (10.8%), to back and spine (9.9%)

and to head and face (9%) with 11 concussions. A typical fall for involved the driver being dislodged laterally from the sulky or catapulted forward into the air by the sulky. These fall types are illustrated in the video frames in Figure 1. The impact velocities observed were in the order of 5.5 to 7.0 m/s, from heights of up to 3.2 metres (or two horse heights).

A.  B. 

**Figure 1 Frames from a video of a harness racing incident, from Gibson and Thai (2007): A. The sulky flips over and the driver is thrown laterally onto the track; B. The driver is flipped forward onto the track.**

For the jockeys in thoroughbred racing, Saxon et al (2006), with 1565 injuries reported, the most common injuries were to upper and lower limbs (15% and 25% respectively), to shoulder and clavicle (17%), to chest (7%), to back and spine (21%) and to head and face (11%), a similar ranking of body regions injured to harness racing drivers. The injuries to the jockeys were of greater severity with 78% of the jockeys with injuries suffering a fracture of some kind and more spinal injury. A typical fall for a jockey involved either being dislodged forward over the horse's head or laterally from the horse. The impact velocities observed were in the order of 8 m/s to 14.0 m/s, from heights of up to 3.2 metres (or two horse heights). For the individual race falls studied nearly all had injuries of MAIS ≥2. An example of a race fall is presented in Figure 2. Jockey 1 suffered fractures at T4 and T6 and bruising - due to multi-axial loading of the spine, including: compression due to impact to the crown of the head; full forward flexion at the waist; left lateral flexion of the torso; and, some rotation of the spine. Jockey 2 suffered bruising and swelling of the lower legs and ankle from the fall.

A. 

B. 


**Figure 2 Frames from a video of a thoroughbred race incident, from Saxon et al. (2006): A. Jockey 1 tumbles forward over the horse's head; B. Jockey 2 holds onto the reins as he is thrown laterally from the horse as it tumbles.**

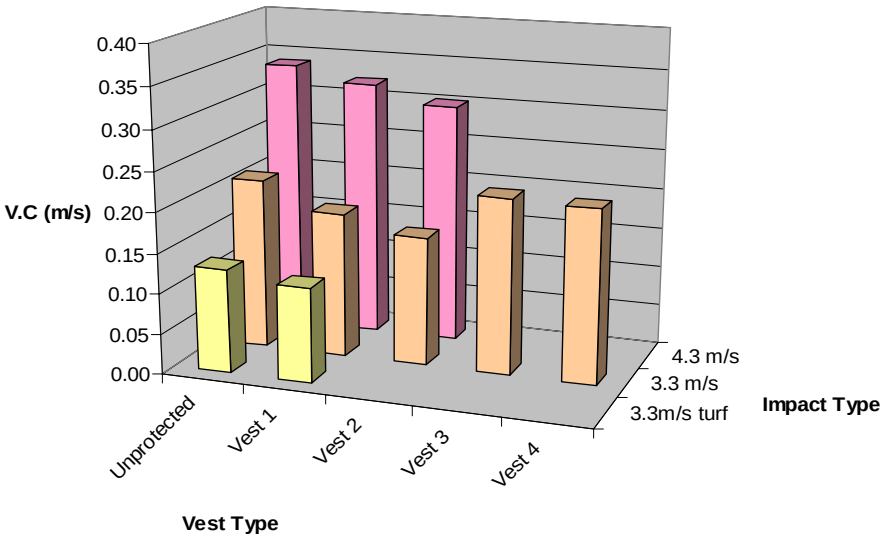
Dynamic tests were made to measure the impact characteristics of the track surfaces and the capabilities of the protective equipment. The testing included on site drop testing of the track surfaces at several different venues using the THOR headform and a 22 kg impactor in order to obtain the

characteristics of the track surfaces. In the laboratory, samples of the currently used helmets and vests were tested using current biomechanical test methodology from the automotive industry, which made use of the advanced THOR dummy biofidelic head and chest forms, GESAC (2001).

Drop testing of the track surface demonstrated significant differences in the characteristics of the surfaces. For harness racing tracks in Australia, a crushed granite track surface with no guard rail is used. The harness racing track was a hard surface somewhat similar to the rigid anvil used in the helmet and vest testing. Thoroughbred racing uses a turf track with metal guide rail on rigid supports. The turf surface was relatively soft in comparison to the PPE impact test methods. Although falling to the track surface was the major cause of injury in both forms of racing, rigid sharp impacts to the head and torso from impacts with such objects as horses hooves (with metal shoes), the guard rail (in thoroughbred racing) and the sulky (in harness racing) were also observed.

To reproduce the head impacts observed with the track surface, the THOR headform was dropped with and without a currently approved helmet on both of the surfaces (turf and crushed granite). The bare headform was then tested in the lab on the rigid steel anvil with and without a similar helmet fitted. The test results indicated that the headform impacts on the crushed granite track surface gave similar accelerations to the flat impacts used for the AS/NZS 3838 Equestrian Helmet Standard energy absorption test. The turf track surface however was significantly more resilient and the helmet offered little extra protection at the lower end of the measured fall heights for a jockey.

For the protective vest testing a resilient pad was developed to have the same stiffness characteristics as the turf track surface. A test method based on the low speed (4.3 m/s) 22 kg pendulum calibration procedure of the THOR dummy chest was used, GESAC (2001). This low speed test approximates the threshhold of injury to the PMHS tested by Kroell et al. (1971). Four different models of protective vests were tested when fitted to the THOR and the results compared in terms of V*C, see Figure 3, Ridella and Viano (1990). It was found that for the impacts on the simulated turf all the vests were ineffective, for rigid impacts at 3.3 m/s and 4.3 m/s to the chest Vest 1 and Vest 2 were effective and offered some protection against injury, but Vest 3 and Vest 4 gave no such protection.




| | Unprotected | Vest 1 | Vest 2 | Vest 3 | Vest 4 |
|---|---|---|---|---|---|
| 4.3 m/s | 0.339 | 0.321 | 0.300 | | |
| 3.3 m/s | 0.214 | 0.180 | 0.160 | 0.218 | 0.215 |
| 3.3m/s turf | 0.129 | 0.117 | | | |

**Figure 3 Test results of the four vests under different test conditions.**

## DISCUSSION

Dynamic testing with the THOR head and chest were used to compare the performance required by the mandated standards testing of current in use helmets and vests with accepted biomechanical tolerance limits for the head and chest and the loadings obtained from reconstructing typical race falls. Effective PPE are of particular importance in both forms of racing for differing reasons. Jockeys are young and fit but fall more frequent with greater severity and suffer greater more frequent injury when compared with the drivers in harness racing, who are significantly older and heavier.

The level of protection currently given to the jockeys in racing by the mandated helmets and vests is inadequate. The current helmets must better protect the face and reduce concussion in less severe impacts while still giving protection for high severity impacts. The vests must give greater impact protection to the chest and be less restrictive of the motion of the jockeys. The video analysis did not support the often stated idea that jockeys reduce the effect of the fall by tumbling. The protection for the harness drivers with the current equipment is satisfactory but improvements to the helmet (and standard) could further reduce the incidence of concussion.

A limitation for the study was the analysis presented was based on incomplete existing incident data collected for other purposes and not an inclusive properly designed and coded injury database. The study only reviewed the protection equipment used by jockeys and harness drivers in racing in Australia. One successful outcome of the work has been the implementation of a more comprehensive data collection for the purpose of monitoring jockey injury in thoroughbred racing, Saxon and Foote (2006).

## CONCLUSION

This project is the first detailed analysis of the injury mechanisms of racing falls in either of these forms of equestrian sport. The biomechanical analysis makes use of current injury minimisation techniques by applying the injury tolerance data and test capability of the THOR test dummy to sporting injury. The requirements of the PPE for these two forms of the sport differ greatly.

The current forms of PPE, vests and helmets, were found to be effective for the drivers participating in harness racing, but for the jockeys some improvements to the helmet and vest standards are required:

- Th**e helmets** need to afford improved protection to the facial region and to the prevention of concussion while maintaining the protection in more severe impacts.
- The **vests** need to afford improved protection to the chest while giving more flexibility and controlling thermal stress.

## REFERENCES

GESAC, 'Biomechanical Response Requirements of the THOR NHTSA Advanced Frontal Dummy.' (Revision 2001.02, 2001), Report No: GESAC-01-04, 2001.

Gibson T and Thai K, 'The Effectiveness of Safety Equipment in Harness Racing.' HIE Report for the Australian Harness Racing Council, 2007.

Kroell, CK, Schneider, DC, & Nahum, AM, 'Impact tolerance and response of the human thorax', SAE 710851, 15th Stapp Car Crash Conference, 1971.

Ridella S and Viano D, 'Determining Tolerance to Compression and Viscous Injury in Frontal and Lateral Impacts.' Proceedings of 34th STAPP Car Crash Conference, 1990.

Saxon J, Foote C, Gibson T and Thai K, 'Health and Safety in Australian Racing – National Jockey Health and Safety Review.' Report for Racing NSW, Racing Victoria and Racing and Wagering WA, 2006.