











**Test 3 (side drop)**

The contour map showing the peak forces recorded by each cell for Test 3, where the equine cadaver was dropped on its side directly onto the load cells without an ATD in place, is given in Fig. 14. Another approximate overlay schematic for this set-up is shown in Fig. 15. This reveals a very localised peak force (around the pelvis of the horse) of around 15 kN.

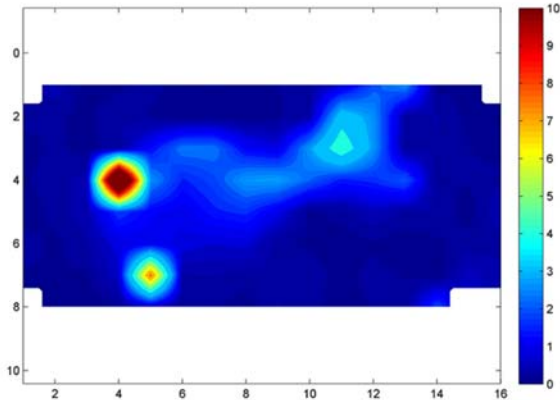


Fig. 14. Contour map of peak forces (in kN) in Test 3.

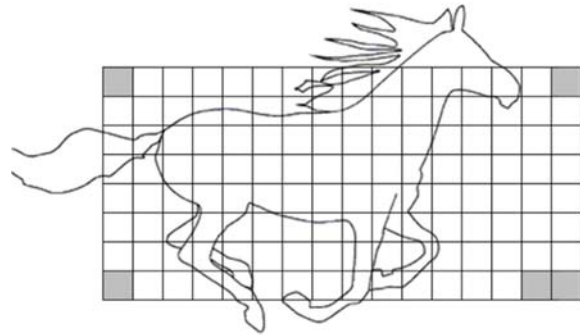


Fig. 15. Schematic of approximate position of horse with respect to the force plate, Test 3 (no ATD torso).

Figure 16, showing the force-time histories of the cells in the first four columns, highlights the peak force as being restricted to one cell. It also shows the impact covering a shorter time period of around 75 ms, which is expected given that the impact in Test 3 was directly with the hard surface of the load cells.

Time histories for all of the load cells in Test 3 can be viewed in Fig.17, where it may be noted that the total force over the entire measurement plate was around 70 kN.

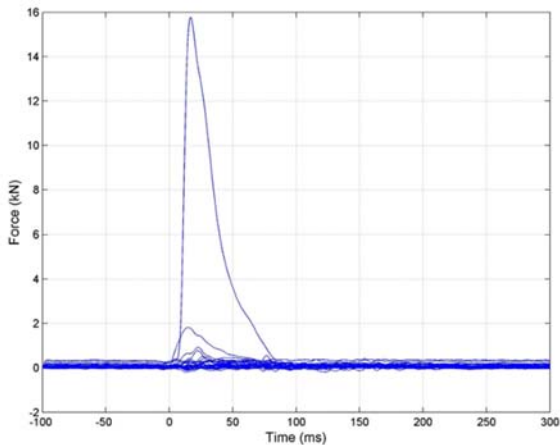


Fig. 16. Force-time for individual load cells for Test 3.

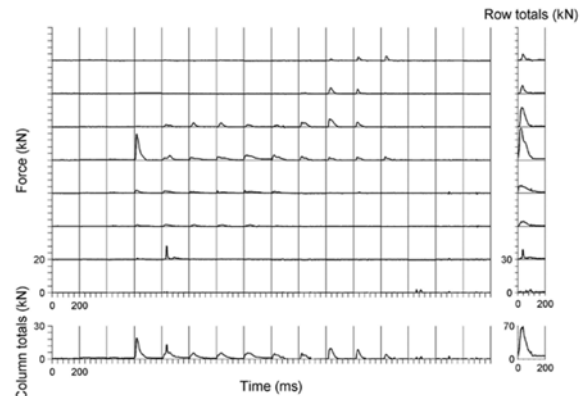


Fig. 17. Force-time for load cells for Test 3.

**Test 4 (back drop)**

In the fourth test the equine cadaver was dropped directly onto the load cells on its back. A contour map of the peak forces (see Fig. 18) shows two distinct peaks corresponding to the horse’s shoulder region and haunch. The peak forces recorded in these locations were around 12 kN and 17 kN, respectively.

The force-time information for the cells in Test 4 can be gleaned from Fig. 19. The overall force across the cells is around 70 kN, as in Test 3.

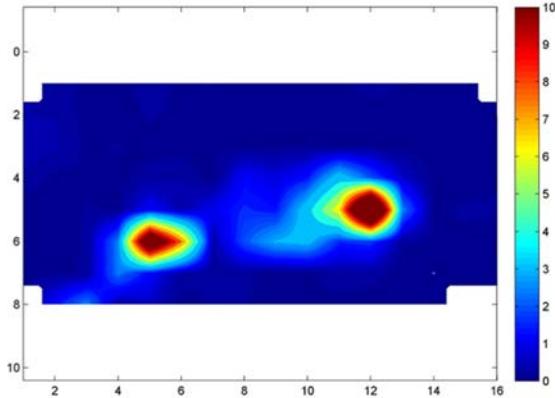


Fig. 18. Contour map of peak forces (in kN) in Test 4.

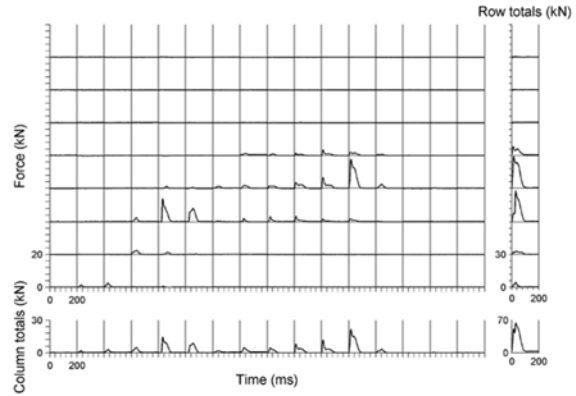


Fig. 19. Force-time for load cells for Test 4.

**Summary of results**

The key findings with regard to the behaviour of the body protectors around the ATD torso are shown in Table I.

TABLE I  
PEAK CHEST DEFLECTION AND SEVERE INJURY RISK FOR ATD TORSO

	Peak chest deflection (mm)	Injury risk (% risk of severe chest injury)
Air jacket + body protector	66	81
Body protector only	77	94

The air jacket was shown to slightly reduce the compression of the ATD’s chest and therefore the predicted risk of severe thorax injury. This means that it could have a beneficial effect in reducing the likelihood of a severe injury being sustained in an accident where a horse falls onto a rider. However, with or without the air jacket, there was a high probability of a severe injury being sustained by a rider in the loading condition created for these tests.

**IV. DISCUSSION**

Improving safety of riders has been high on British Eventing’s agenda for a number of years. The results of the present study revealed that while air jackets may have some safety benefits, fatal and serious injuries are still highly likely to occur should a horse fall directly onto a rider.

While the results provide an initial indication of the effectiveness of air jackets, there are a number of areas that require further exploration. The ATD used in the tests represented the average height and weight of a 45-year-old male, and results may vary for riders of different statures and ages. For example, risks may be slightly lower for younger riders, but substantially higher for older riders due to the fact that bone condition changes with age. It is expected that the risk of receiving a serious chest injury in these tests would be likely to approach 100% for older riders with or without the air jacket. It may be that there are combinations of loading condition and rider for which this design of jacket is unable to offer meaningful protection.

To put this into context, for car occupants involved in a crash, a younger occupant's probability of death is 1.36 times greater with rib fracture than without, and an older occupant's probability of death is 2.14 times greater with rib fracture than without [3]. For car occupants, the risk of death for a younger occupant with 50% probability of serious rib fracture is 18%, compared with 57% for older occupants. Although not directly applicable to the crush loading investigated in the present study, this is indicative of the likely increased morbidity for older riders for a given injury risk.

It should also be remembered that these tests involved one loading condition, with a relatively low drop height. Other loading conditions may be more or less severe, with concomitant differences in the injury risk. The exemplar equine cadaver was also relatively light in comparison with a typical eventing horse; a heavier horse or greater fall height would be expected to increase the risk of severe chest injury.

Several tests were performed with the same specimen and it was not possible to determine whether there was any degradation of the specimen from test to test (for instance, fractures that would reduce the stiffness of the specimen). This introduces some uncertainty to the results.

One element not assessed in the present study was whether the air jacket protects the rider in the initial ground contact, prior to crush loading from the horse. If so, then there could be a benefit in that the horse would be less likely to land on an injured, and therefore weakened, rib cage. This may particularly be the case with partial crush loading, where the horse doesn't fall as directly or severely onto the rider as the ATD in the present study.

Tests on other designs of air jacket (or other PPE intended to reduce the injury risk) using other specimens would not be directly comparable with these test results. If comparative data is required for different PPE designs, then a more consistent test object would be required, such as a mechanical surrogate for an equine cadaver. The measurements made in these tests provide baseline data that could be used to develop such a test tool.

## V. CONCLUSIONS

Results from the tests showed that the air jacket slightly reduced the compression of the ATD's chest and subsequently the predicted risk of severe chest injury from 94% to 81%. This means that it could have a beneficial effect in reducing the likelihood of severe injury from a horse falling onto a rider. However, there is still a high probability of riders sustaining a severe injury, even when wearing the air jacket. So while the air jacket may provide some safety improvements, it is unlikely to prevent fatalities should a horse fall directly onto a rider.

Data have been generated with regard to the forces applied by a falling horse. These data may form a baseline from which a suitable test procedure for PPE could be developed.

## VI. ACKNOWLEDGEMENTS

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## VII. REFERENCES

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