

## Damage to Real World Equestrian Helmets Sustained from Impact against Different Surfaces

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### I. INTRODUCTION

Concussion is one of the most common injuries in equestrian sports [1-5]. Currently, the majority of the literature in equestrian head impact biomechanics has focused on the performance of helmets to rigid surfaces in order to reduce risk of injury through helmet design [6-8]. Although there is a risk of sustaining injury from impacting rigid surfaces in equestrian sport, concussions are more commonly a result of impacts to softer surfaces, such as turf [9]. Little research has been performed to evaluate equestrian helmet's performance for impacts to turf [10,11] and, as a result, little is known about how equestrian helmets perform under common accident conditions. Differences in loading conditions have been shown to affect the protective capabilities of helmets, as helmets have been less effective at attenuating energy in impacts against highly compliant surfaces [10-12]. A better understanding of how different impact surfaces influence equestrian helmet performance in real world accident conditions may provide a more effective strategy for developing a safer riding environment through improved helmet design. One method that can be used to assess helmet performance in real world conditions is to analyse damage sustained by the helmet during an impact [13-17]. The purpose of this research is to evaluate the influence of impact surface on such damage during real world equestrian accidents.

### II. METHODS

#### *Helmet and Accident Data Collection*

Helmets and accident report forms were collected by helmet manufacturers and trade associations; a crash replacement policy encouraged the return of damaged helmets. Cases included in this research were required to have an accurate and complete description of the impact surface and injury outcome of the accident. Impact surfaces included in this research were those to a road (e.g. concrete, tarmac) and to turf. If there was no clear description of these criteria, the case was excluded from the research dataset. Additionally, cases in which multiple impacts were described in the accident report or found on the helmet were also excluded from this research. Of the 101 helmets collected, 20 cases met the criteria and were included in this analysis.

#### *Helmet Damage Analysis*

Helmets were inspected visually for any evidence of damage to the outer shell, such as cracks, scratches, scuffs or tears in the fabric. The helmets were then disassembled by melting the glue between the energy-absorbing liner and shell, allowing for both parts to be separated without causing any further damage. The interior of the shell was then inspected for any delamination of the composite or plastic material. The liner of the helmet was examined for residual crush. Maximum residual crush of the energy-absorbing liner was measured using calipers at the centre of impact and compared to the corresponding undamaged side, or to an exemplar helmet for more popular models. Mann-Whitney U tests were conducted to compare the extent of residual crush of the helmet liner for impacts to road and turf. The confidence interval was set to 95%.

### III. INITIAL FINDINGS

Of the 20 cases examined, four were impacts to a road and 16 were to turf. Two of the four road impacts resulted in concussion and no injury was reported for the others. For the turf impacts, 14 concussions and two null cases were reported. Table I describes the visual damage observed on the accident helmets. Figure 1 presents the distribution for residual crush measured from the helmet liner. Impacts to a road were found to

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have significantly higher residual crush of the helmet liner ( $27.03 \pm 14.16$ ) compared to impact to turf ( $8.51 \pm 12.07$ ).

TABLE I

DESCRIPTION OF VISIBLE DAMAGE OBSERVED FROM ACCIDENT  
HELMETS (N=20: 4 ROAD IMPACTS + 16 TURF IMPACTS)

Damage Location	Type of Damage	% of All Cases (N=20)	
		Road	Turf
External Shell Damage	Cracked	5	5
	Scratched/Scuffed	5	15
	None	10	60
Internal Shell Damage	Delamination	5	15
	None	15	65
Liner Damage	Residual Crush	20	35
	None	0	45
Overall	Damage Found	20	45
	No Damage	0	35

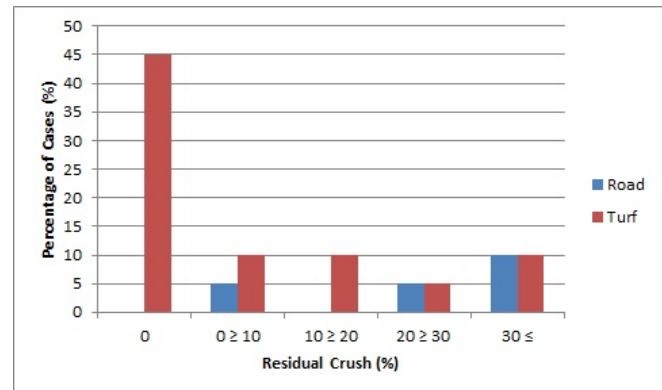


Fig. 1. Distribution of residual crush in helmet liner as sustained from impacts against different impact surfaces in real world equestrian accidents.

#### IV. DISCUSSION

All road surface impacted helmets were found to have liner damage, with some also having shell damage. Damage to the shell and liner are the principal modes of failure and energy attenuation of equestrian helmets. Therefore, the helmets involved in road surface accidents are absorbing energy as expected, which reflects the fact that these helmets are designed and tested for impacts against rigid surfaces. However, not all the helmets involved in impacts to turf surfaces sustained damage, although a majority of these helmets were damaged. This highlights the importance of wearing a helmet while participating in equestrian sports.

More significant, however, is the fact that no damage to either the shell or liner was found in 35% (seven cases) of all the helmets analysed. In all cases, these particular impacts were to turf, which is of particular concern as five of these seven cases resulted in concussion. In these five cases, the helmet absorbed insufficient energy to prevent these riders from being concussed. Research by Bourdet and Willinger [18] noted that 40% of head impacts in professional horse racing occur below the test line for equestrian helmet standards. Other researchers investigating impacts to compliant surfaces have shown that impact energy that is not transmitted to the head is absorbed by both the helmet and the compliant surface, with potentially insufficient energy being absorbed by the helmet [10-12]. Both of these possibilities could explain why no helmet damage was observed in these seven impact events. The results of this present study raise the question of whether, for real world impacts to turf, equestrian helmets provide adequate protection to jockeys?

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