

Aircrew Head Injury Protection

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Introduction

The necessarily violent nature of an aircraft ejection means there is a significant risk of injury, particularly to the head. At present, aircrew mitigate this head injury risk with helmets designed and tested to a motorcycle derived impact standard from the 1980s. This research looks to identify the historic risk of head injury faced by aircrew, the biomechanics of aircrew head impact and the common brain pathologies seen. Helmet impact testing, computational modelling and the development of appropriate injury risk functions has been carried out to inform future aircrew helmet impact standards.



Methods

1. Historic injury risk

A review of RAF Centre of Aerospace Medicine accident database archive of all UK ejections between 1972 to 2023 was carried out. Statistical analysis was used to identify the relationships and interactions between ejection speed, aircraft type and the head injury pathologies sustained. Multibody modelling and sled test ejection seat data were used to collect information on head impact kinematics.



2. Improving helmet testing methodology

The historic head injury analysis was used to inform impact conditions for helmet impact testing, including impact surface, location and angle. A series of impact tests were carried out using a modern 'biofidelic' test headform on an unconstrained drop tower. 6 d.o.f. accelerometers were used to capture head kinematics during impact tests of representative helmet impacts.



3. Injury risk function development

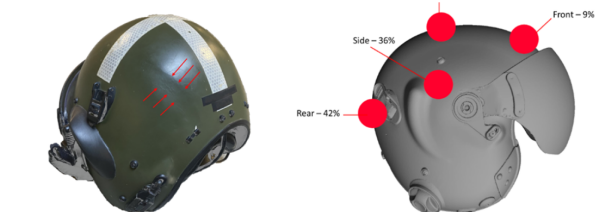
Kinematic data from NFL head impacts was used to generate a loss of consciousness (LOC) risk function. An FEM TBI model of the brain is currently being used to collect information on strain and strain rate in the brain for representative impact conditions. Loading conditions from sled test and helmet drop tower data were used to load the FEM model.

“ Developing **novel** impact tests and brain injury thresholds to aid the development of **safer** helmets ”

Results

1. Historic injury risk

Loss of consciousness (LOC) was found to be the dominant brain injury sustained in 26 of 33 head injuries resulting from 276 ejections. The rear and side of the helmet were the most commonly impacted zones. Helmets were more likely to impact flat and edged shaped objects.

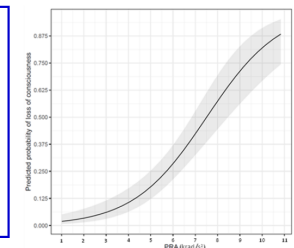


2. Improving helmet testing methodology

Head kinematic data was collected using the biofidelic testing methodology. A range of helmets were tested against impact conditions seen in real life ejection events. The data generated offers improved headform kinematics with a low level of variance compared to legacy aircrew helmet testing.

3. Injury risk function development

Logistic regression curves for LOC were generated for kinematic measures such as rotational acceleration, rotational velocity and the Brain Injury Criterion (BrIC). Brain strain and strain rate has been calculated for NFL head impacts with known kinematics as well as for ejection sled tests and helmet drop tower tests.



Discussion

There continues to be a risk of head injury in aircrew who eject out of combat aircraft. The most common brain injury seen was a loss of consciousness which is known to be closely associated with rotational kinematics of the brain. At present, aircrew helmets are not required to demonstrate rotational protection. A novel drop test and injury risk function for loss of consciousness has been developed to better assess helmets against this measure.

Further work is underway to update the kinematic injury risk curves with strain and strain rate data from the brain and specific regions of interest such as the brainstem and nuclei known to be involved in consciousness. The development of a loss of consciousness risk function for helmet testing is likely to have utility in other applications beyond military aviation.

Bio



Alasdair Mackay is a 3rd year PhD student in the HEAD Lab under the supervision of Mazdak Ghajari. He is also a GP and Specialist Registrar in Aviation and Space Medicine for the RAF.

References

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