

Testing helmets for trips and falls: towards the development of an industrial helmet rating program

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Introduction

Traumatic Brain Injury (TBI) is a common workplace injury, affecting **57 million** people globally each year [1]. Work-related TBIs (Wr-TBIs) make up 17.9% of these cases, with **falls being the leading cause (50-70%)** [2][3]. Current safety helmets meet standards like EN379, which focus on heavy and sharp object impacts, but these account for only 17% of Wr-TBIs.

Our study used human multi-body models to simulate falls and trips, identifying **key head impact conditions** such as location, speed, and angle. We tested industrial helmets under these conditions to assess their effectiveness, providing insights into helmet performance in real-world fall scenarios.

Table 1: The parameters of the impact test condition.

Impact Conditions	Trip	Fall 1	Fall 2.1	Fall 2.2	Fall 3
Impact speed (m/s)	3.9	3.8	5.5	5.5	5.5
Impact angle (degree)	75	45	75	75	75
Elevation angle (degree)	35	45	40	25	40
Azimuth angle (degree)	45	0	0	0	180

Methods

Five impact conditions are summarised in Table 1. Using the latest biofidelic EN17950 headform equipped with a DTS 6DX PRO sensor package and wireless datalogger, we measured linear accelerations and rotational velocities along three axes for each impact. Data was collected at 20 kHz and filtered per ISO 6487 standards. Peak values of **linear acceleration (PLA)**, **rotational acceleration (PRA)**, and **rotational velocity (PRV)** were extracted as head injury metrics. Each test condition was repeated three times with three different samples.

Results

Figure 3 illustrates the **effects of various impact parameters** on helmet performance, including surface conditions, external helmet design features, and different EPS coverage. These parameters significantly influence safety performance, as shown in both the plotted time history head kinematics and high-speed video snapshots.

Fall 2.1 and Fall 2.2 resulted in high **PLAs exceeding 250g**, highlighting helmet safety performance failure. Fall 2.2, in particular, had impacts closer to the rim, leading to less protection. Fall 2 impacts produced lower rotational motion due to a larger, less oblique impact angle of 75° compared to Fall 1 impacts. Interestingly, Trip conditions produced a higher PLA than Fall 1 despite similar impact speeds.

Discussion

We tested industrial helmets under representative oblique impacts from trips and falls. Current helmets show **poor repeatability** and are not designed for these conditions, leading to **inconsistent protection in real-life scenarios**. A potential limitation of this study is the possibility for some helmets to impact the edge of the anvil, which can affect results for helmets with features like the hump.

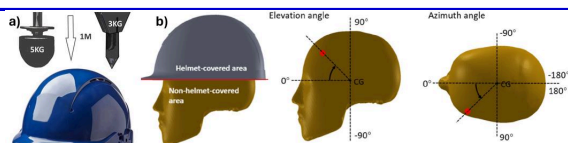


Figure 1: a) EN 397 impact test; b) Elevation and azimuth angle.

“ **Comprehensive helmet rating program** to reduce work-related TBIs from trips and falls, aiming to establish **new industrial helmet safety standards** ”

Traditional Construction Hard Hat (EN 397)



Climbing-style helmets (EN 397; EN 12492)



Figure 2: Types of hard hats.



Figure 3: Different surface conditions.

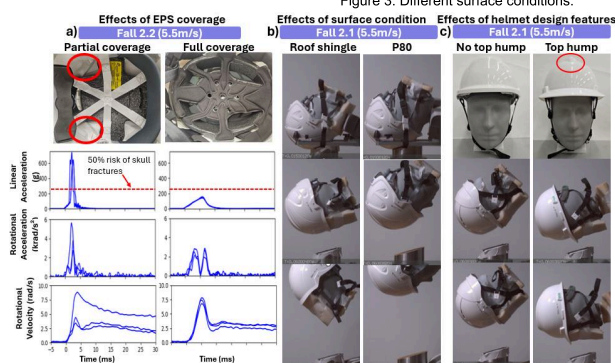


Figure 4: Impact of EPS Coverage, Surface Condition, and Helmet Design Features

Key Findings

EPS Coverage

- Climbing-style helmets with EPS foam generally improve protection but do not completely prevent bottoming out.
- Unlike bicycle helmets, climbing helmets have inconsistent EPS thickness and coverage, leading to varied performance.

Surface Conditions

- Helmets showed greater rotation and similar or lower linear acceleration on the roofing shingle surface.
- All impacts on the P80 surface, except Fall 1, produced significant vertical rebounds.

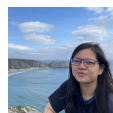
Helmet Design Features

- External elements like humps on helmets increase rotational velocity.
- These elements cause inconsistent test results, as safety performance varies significantly with small changes in impact location.

Conclusion

Helmet safety performance varies significantly due to design factors such as EPS inclusion, specific features like humps. It is crucial for test protocols to include representative head impact conditions, enabling helmets to be better designed to protect against trips and falls. This study aims to develop a comprehensive rating program for industrial helmets, driving continuous improvement and enhancing safety standards.

Bio



Rachel Tan is a research assistant in the HEAD Lab. Her current research focuses on the safety performance and test protocols of helmets, aiming to better represent real-world impact scenarios, particularly concerning traumatic brain injury.

References

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[3] Liu et al., Work. 2011

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