Materials and Methods

1. Experimental setup

One representative off-the-shelf Type 1 helmet model was used in this study. A Type 1 helmet is designed for top impact protection only and is not designed for protection from lateral impacts to the front, side, or rear of the head. In the current study, only Type 1 impact tests were performed: a free-falling impactor is impacted on the top crown of the helmet shell that is fitted on a fixed headform. The experimental setup is similar to those used in our previous studies (Pan et al., 2021; Wu et al., 2018). Helmet drop impact trials were performed using a commercial drop tower test machine (H.P. White Laboratory, MD, USA), which complies with the ANSI Z89.1 standard. The forces transmitted to the headform were measured using a force sensor (Model 925M113, Kistler, Amherst, NY, USA), which is uniaxial and has a capacity of 22.2 kN (5 x 10^3 lbf) and an accuracy of +/- 2.5 % in full scale. The force sensor was installed between the base of the tower and the headform. The velocity of the impactor just before impact was measured via an optical sensor built in the system. The impactor was semi-spherical with a radius of 48 mm at the striking face. In the current study, two impactors were used: 3.6 kg and 5.0 kg. The headform is made of aluminum and had a mass of 3.64 kg. The force data were collected at a sampling rate of 25 kHz.

2. Test procedure

A total of 19 drop impact trials were performed in two groups. In group (a), 10 drop impacts were performed using the 3.6 kg impactor at 10 drop heights from 0.31 m (1.0 ft) to 1.93 m (6.3 ft). In group (b), 9 drop impacts were performed using the 5.0 kg impactor at nine drop heights from 0.22 m (0.72 ft) to 1.32 m (4.32 ft). Each of the impact trials was replicated four times. Each drop impact

was performed using a new helmet sample, which was disposed of following the drop impact tests. A total of 76 [(10 + 9) × 4] drop impacts were performed. The recorded time-histories of forces were processed using a custom program developed using MATLAB software to find the maximal peaks during the impacts. The unfiltered raw data were used in the determination of the maximal peak values during the impacts.

3. Tests to determine the system frictional energy loss

The frictional energy loss in the system during the impacts was tested using both 3.6 kg and 5.0 kg impactors. The frictional energy loss (δ) in the system during impacts were estimated by dropping an impactor at a height of h:

$$\delta = \frac{gh - 0.5 \cdot v^2}{gh} \cdot 100\ \%$$

where v is the measured velocity just before impact and g is the gravitational acceleration.

References

Wu JZ, Pan CS, Ronaghi M, Wimer BM. Testing the shock protection performance of Type I construction helmets using impactors of different masses. Biomed Mater Eng. 2024;35(4):351-363. DOI: 10.3233/BME-230173.

Wu JZ, Pan CS, and Wimer BM, "Quantification of the shock absorption performance of construction helmets in top impact" (Presentation, 42nd Annual Meeting of the American Society of Biomechanics, Rochester, MN, August 8-11, 2018).