OBLIQUE IMPACT TESTING OF BICYCLE HELMETS

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INTRODUCTION

Of the 1,300 persons that die each year from bicycle accidents, 90% are due to head trauma (Waters, 1986). The most common injury mechanism is angular head acceleration caused by oblique impacts (Otte, 1999).

In stark contrast, contemporary test standards for bicycle helmets simulate perfectly radial impacts and assess linear acceleration only. Albeit oblique head impacts scenarios have been simulated, experimental setups were too complex for adaptation in test standards (Aare, 2003).

This research introduces a modification of a standard drop tester for bicycle helmets to enable oblique impact simulation and angular acceleration assessment. Furthermore the dependence of friction in oblique impacts was evaluated.

METHODS

Four aspects of a monorail guided drop tester, compliant to bicycle helmet test standards CPSC §1203.17, were modified (Figure 1): 1) to simulate oblique impacts, the standard flat anvil was replaced by a 30° oblique anvil; 2) to allow for unconstrained motion during the oblique impact, the head-form was connected to the drop follower with three highly flexible steel cables; 3) to measure linear acceleration in oblique impacts, the standard uniaxial accelerometer mounted at the headform center of mass was replaced by a biaxial accelerometer (PCB Piezotronics 356B21, Depew, NY); and 4) to measure angular acceleration in oblique tests a second uniaxial accelerometer (ACC103, Omega, Stamford, CT) was mounted at 90mm horizontal distance to the center of mass. Acceleration differences between the two accelerometers were used to estimate the angular acceleration pulse during helmet impact under the assumption of headform rotation around a transverse axis.

Three impact scenarios were investigated: 1) Perpendicular, 2) 30° oblique, high friction interface (HF), 3) 30° oblique, low friction interface (LF). All drop tests were performed with a drop-height of 1.2 m, equivalent to CPSC §1203.17 curbstone impact testing, to approach an impact velocity of 4.9 m/s.

Figure 1: a) perpendicular and b) oblique impact test setup.

Perpendicular impacts were conducted for comparison to conventional helmet drop-testing. Oblique impacts were conducted with either a LF interface by means of a lightly greased anvil surface, or with a HF interface, for which a 60-grit sandpaper was glued on the anvil.

In each of the three scenarios, three contemporary microshell helmets (Bell Reflex, Rantoul, IL) were impacted. Results
were presented in terms of linear acceleration and angular acceleration for all test scenarios.

RESULTS

Perpendicular impacts yielded an average linear acceleration of 187.5 ± 18.6 g, 30° LF and 30° HF yielded a significantly lower linear acceleration (p<0.05) of 151.3 ± 1.8 g and 150.11 ± 13.28 g, respectively (Figure 2). No significant differences in linear acceleration were noted between 30° LF and 30° HF oblique impacts (p=0.88). The angle between the drop trajectory and the acceleration vector was 31.2°±0.2° and 29.2°±1.3° for 30° LF and 30° HF, respectively.

Furthermore, oblique impacts on the LF surface induced significantly less rotational acceleration as oblique impacts on the HF surface (p<0.01).

DISCUSSION

Oblique impact tests can be conducted with relatively simple modifications of a standard drop tester to account for both, linear and angular acceleration during head impact simulation. At a later time we will implement two biaxial accelerometers, which are necessary to acquire the absolute angular acceleration independent of headform rotation.

The significant decrease in linear acceleration for oblique impacts may be attributed to energy transfer from linear to angular acceleration. This oblique impact test did not account for neck constraints and is therefore not intended to explore complex head/neck kinetics following the initial impact. However, it effectively captured the angular acceleration pulse generated during the initial impact. As such, this test addresses the consistent request for consideration of oblique impacts in helmet testing (Mills, 1997) in a simplicity that may be amendable for implementation into existing test standards. Such an advanced test standard is a likely prerequisite to trigger advances in helmet design aimed to protect the head from both, linear and angular acceleration.

REFERENCES


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