A New Breed of Type II Helmets: Are Some Safer than Others?

Michael Bottlang, PhD,
Director, Legacy Biomechanics Laboratory
Legacy Research Institute, Portland, OR

The latest generation of helmets have impact liners to meet ANSI Type II requirements for front, side and rear impact protection. In contrast, Type I helmets are only tested and optimized for crown impacts. Several of these new Type II helmets also offer technologies to dampen rotational forces and torque that is the main cause of concussions and brain injury. Researchers of the Helmet Impact Testing (HIT) facility at the Legacy Biomechanics Laboratory recently took these new Type II helmets to the test, measured their impact performance and found rather large differences in their protective performance.[1] Their test results can facilitate the daunting task of helmet selection by providing clear guidance from physical test data. This article summarizes their findings from side impact tests similar to ANSI Type II and from oblique impact tests representative of slips, trips, and falls.

TYPE II PROTECTION

The US helmet standard ANSI Z89.1 recognizes the fact that old-fashioned strap suspensions can absorb crown impacts, but are basically useless in front, side, and rear impacts. That's why the standard implemented two different levels of testing: Type I testing only evaluates crown impacts. Type II testing also includes impacts to the front, side, and back. In practice, most impacts occur from the sides and only 15% of impact occur to the helmet crown,[2] for which reason OSHA is promoting the switch to Type II helmets.[3] Modern Type II helmets typically replace the strap suspension with an impact liner made of Styrofoam that lines the entire shell and provides all-around impact protection similar to climbing or cycling helmets (Figure 1). However, unlike sports helmets with large vents, a foam liner inside a construction helmet traps heat. Alternatively, WaveCel uses a breathable cellular impact dome in place of Styrofoam to avoid heat stress. This technology has been adopted in over 2 million high-end bicycle helmets where cooling and comfort is most critical.

Figure 1: A) Traditional Type I helmet with strap suspension; B) Type II helmet with foam; C) Type II helmet with Wavecel liner.

Which Type II helmets provide the most protection? The HIT facility tested 7 different Type II helmets from 5 manufacturers: Milwaukee Bolt with and without Impact Armor (IA) liner, MSA V-Gard with and without MIPS liner, Studson SHK-1, WaveCel T2+ Max, and Kask Zenith X2. They provided test results in terms of the impact acceleration transmitted to the head for front, side, and rear impacts (Figure 2). The lower the impact acceleration, the better a helmet absorbed impact force. Results showed over 2-fold differences in force absorption between helmets. On average, the WaveCel T2+ absorbed the most force, followed by the MSA V-Gard. Poor performance in front and side impacts of some helmets was attributed to deficient foam padding or the presence of internal hard plastic projections.

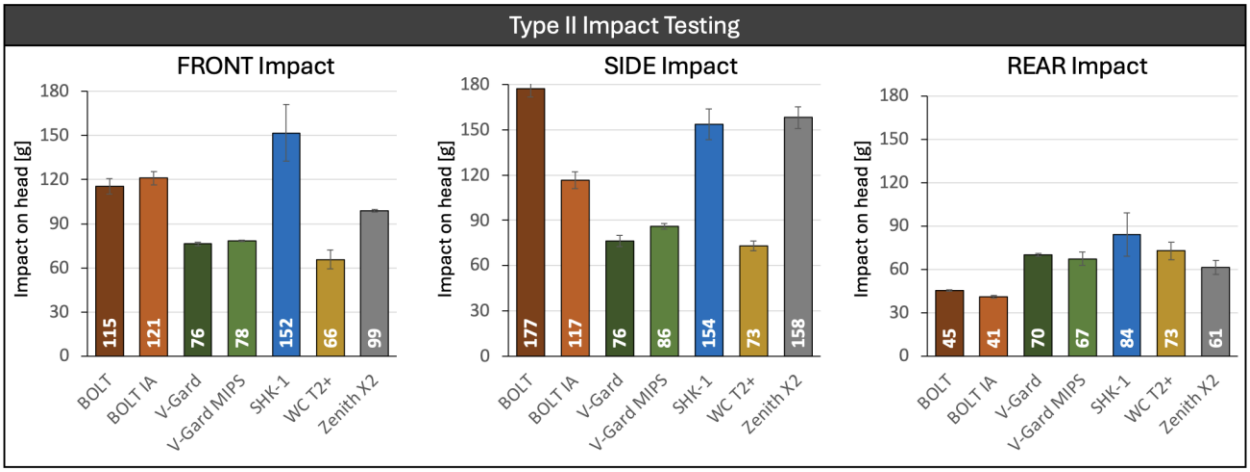

Figure 2: Helmet models exhibited large differences in Type II impact test performance.

BRAIN PROTECTION

There are two different types of head injuries, namely skull fracture and brain injury. Fracture of the hard but brittle skull is caused by a straight impact, like a Type II impact test. In contrast, brain injury is caused by slips, trips, and falls when the head undergoes a short but forceful spin upon impact. The resulting torque or twist of the head can readily damage the soft brain tissues, leading to concussions and traumatic brain injury (TBI). Brain protection from impact torque has been the blind-spot in helmet design. A September 2023 article in Occupational Health & Safety, titled “Addressing an Overlooked Danger”, stated that current helmet standard must be updated to account for rotational force, which is the key cause of concussions on construction jobsites. Each year, over 50,000 work-related non-fatal brain injuries are admitted to hospitals in the United States.[4] Over 60% of these injuries are caused by simple slips, trips, and same level falls. Treatment cost of a single work-related TBI typically exceeds $1 million.[5] Over 90% of such brain injuries occur in absence of a skull fracture, which further confirms that the soft brain is injured by a distinctly different mechanism than the hard skull.

For their helmet testing, the HIT facility of the Legacy Biomechanics Laboratory used a state-of-the-art simulator that includes the instrumented head and neck of a crash test dummy to measure rotational forces in oblique impacts that simulate slips, trips and fall events.[1] This simulator was used to test all seven helmets for their ability to reduce rotational forces during front impacts from a 6’ fall onto a 45º anvil (Figure 3). They measured the rotational force inside the head. These data allow to calculate the predicted risk P(AIS2) of sustaining a grade “AIS2” brain injury.

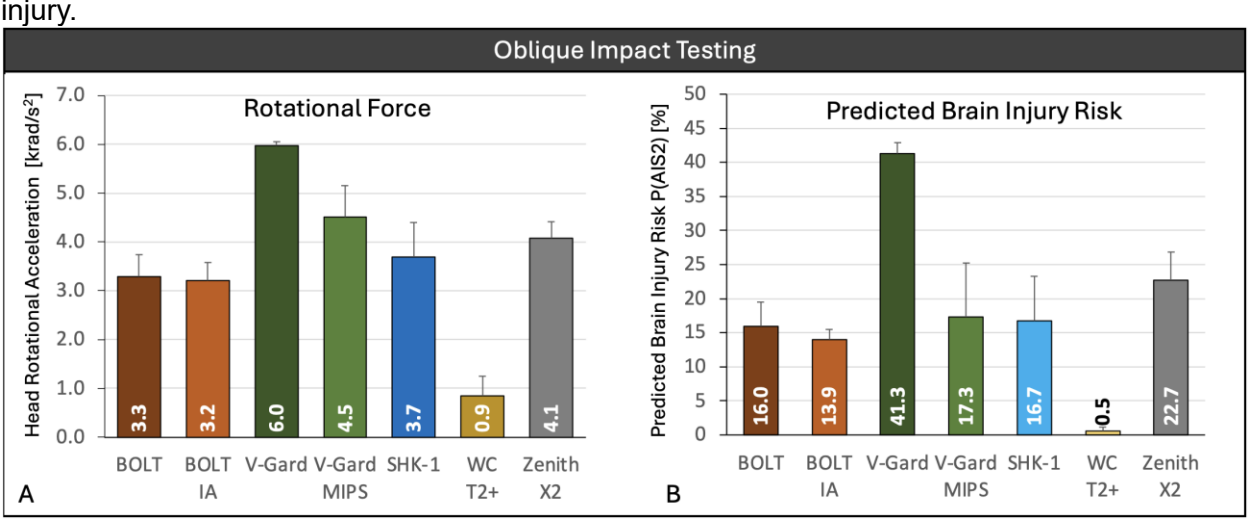

Figure 3: Brain protection provided by helmets differed greatly, as shown by the rotational force measured inside the head (A), and by the predicted risk of sustaining brain injury (B).

They found that adding an Impact Armor (IA) liner inside the Bolt helmet made no significant difference. Adding a MIPS liner to the V-Gard helmet reduced the predicted brain injury risk from 41% to 17%. In the same impact simulation, the WaveCel T2+ helmet provided by far the best protection among all helmets, with a predicted risk of sustaining a brain injury of less than 1%. This exceptional performance of WaveCel helmets might be attributed to the fact that the T2+ helmet was designed from ground up around the WaveCel technology. WaveCel was developed with support of the US National Institute of Health for the sole purpose of reducing rotational forces to lessen the incidence and severity of brain injury.

Other Safety Considerations

A helmet can only provide protection if it stays on the head during a fall. Chin straps can readily prevent a helmet from falling off the head. All of these new Type II helmets come with chins straps. Also, all EN 12492 certified climbing-style helmets come with chin straps. In addition to impact performance, helmets must be comfortable to wear and avoid excessive weight and heat. Unfortunately, Styrofoam liners used in Type II helmets can contribute to heat stress. Breathable cellular liners such as those in WaveCel helmets might allow for better cooling. Finally, helmets should be selected based on their rating, independent of a particular helmet style. All Type II helmet provide better impact protection than Type I helmets. Most climbing style helmets offered prior to 2023 were only Type I rated and therefor provide less impact protection than hard hats with a Type II rating. For this reason, a recent guidance document sponsored by the National Institute of Occupational Safety & Health (NIOSH) clarified that the terms “hardhat” and “safety helmet” denote differences in style and not in performance, for which reason it is important to focus on protective performance.[3]

CONCLUSION

When choosing a helmet based on available evidence of performance, the following three aspects should be considered:

1) Choose a helmet with a rotation-mitigating technology to reduce the risk of brain injury. Since rotational forces can readily be measured in tests, manufacturers should provide data on the relative benefit of their technology compared to standard helmets.
2) Choose a helmet that is ANSI Type II rated to provide protection from front, side, and rear impacts which occur far more often than crown impacts.
3) Choose a helmet with chin straps to ensure the helmet remains on the head during impact.

ABOUT THE AUTHOR

Michael Bottlang is the founder and director of the Legacy Biomechanics Laboratory in Portland, Oregon. His research has been funded by the National Institute of Health and he has published over 80 peer-reviewed papers. Dr. Bottlang is also a founder of WaveCel LLC, a helmet company dedicated to reducing the incidence and severity of brain injury.

REFERENCES

[1] Bottlang M, et al., (2024). Impact Performance Comparison of Type II Safety Helmets with and without Dedicated Mechanisms for Brain Protection. J Forensic Biomech. 15:490.

[2] Gilchrist A, Mills NJ. Construction Site Workers Helmets. Journal of Occupational Accidents 1987; 9:199-211

[3] https://www.cpwr.com/wp-content/uploads/FS-Selecting_Head_Protection.pdf

[4] Konda S, et al., Non-fatal work-related traumatic brain injuries treated in US hospital emergency departments, 1998-2007. Inj Prev. 2015;21(2):115-120.

[5] T.S. Fu, R. Jing, S.R. McFaull, M.D. Cusimano, Health & economic burden of traumatic brain injury in the emergency department, Can. J. Neurol. Sci. 43 (2) (2016) 238–247.