INFLUENCE OF IMPACT LOCATION ON PERFORMANCE OF ROCK CLIMBING HELMETS

Mark Begonia[1], Bethany Rowson[1], Blake Scicli[2] and John Eric Goff[2]
[1] Institute for Critical Technology and Applied Science, Virginia Tech, Blacksburg, VA, 24061, USA
[2] Department of Physics, University of Lynchburg, Lynchburg, VA, 24501, USA

Introduction: Over 4.5 million Americans participate in indoor and outdoor climbing [1], but there is limited published research on head protection used in this sport. The most common head injuries to climbers are concussion or closed head injury, with 75% of injuries resulting from falls and only 8% resulting from falling objects [2]. Rock climbing helmets must pass a performance standard in which a mass is dropped onto a helmeted headform with a load cell at the base of the head [3]. Because the current standard is established for impacts from falling objects, more padding is integrated at the crown of these helmets than at other locations. The purpose of this study was to examine the influence of impact location on rock climbing helmet performance in terms of peak head acceleration. Head acceleration is a correlate to head injury risk, so helmets that reduce acceleration will likely have a lower risk of injury [4].

Methods: Rock climbing helmets were subjected to drop tests using an ISO headform (Size J) instrumented with an accelerometer (Endevco 7264B-2000, PCB Piezotronics) mounted at its center of gravity. Helmet models included the Black Diamond Half Dome (Helmet 1, size M/L), Beal Mercury (Helmet 2, size 54-61 cm), Edelweiss Vertige (Helmet 3, size 54-61 cm), and Petzl Boreo (Helmet 4, size M/L). Each helmet model was impacted at four locations with up to five impact speeds. Impacts started at 2 m/s and progressed at 1 m/s increments up to 6 m/s to cover a wide range of head accelerations and test the upper limits of helmet performance. A sample of each helmet model was tested once at each location and speed until the peak linear acceleration (PLA) exceeded a threshold of 300 g. A cutoff of 300 g was selected because it is used as a threshold in other helmet safety standards, and represents a high risk of severe head injury [4, 5].

Results: All four helmet models had the lowest acceleration values at the top location with PLAs below 200 g at 6 m/s (Fig. 1). For the front and side impact locations, some models had high accelerations at low impact speeds, with PLAs over 300 g at 2 m/s (20 cm drop height) or 3 m/s (46 cm drop height). Helmet 4 was the only model that generated PLAs under 300 g up to 4 m/s at all impact sites.

Corresponding author email: mbegonia@vt.edu

This could be due to its design, which consisted of expanded polypropylene (EPP) lining the entire shell of the helmet rather than just the crown. The manufacturer for Helmet 4 markets its models with both top and side protection, which likely improves the helmet design [6].

Conclusions: The differences in head accelerations found in this study were attributed not only to helmet model but also impact location (front, rear and side). These differences in performance represent opportunities for improvements in helmet design to better protect climbers in the event of a fall or other collision.

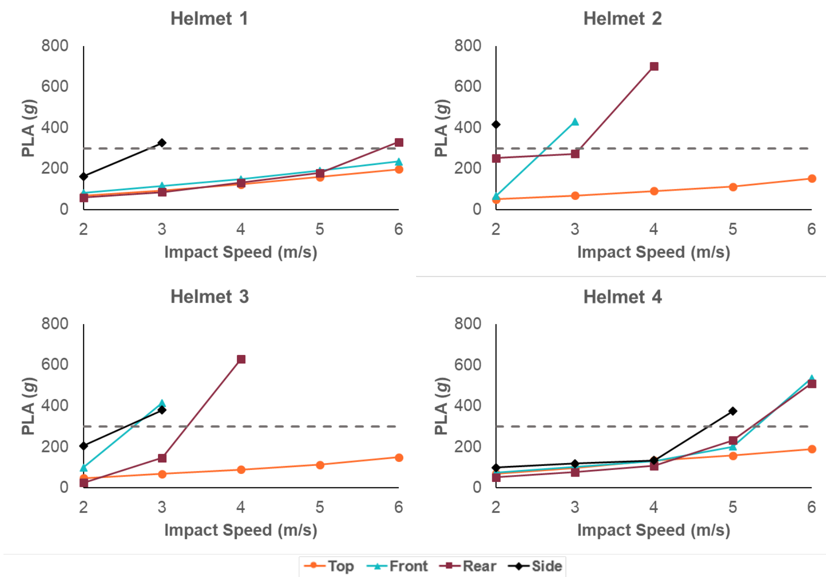

Fig. 1: Comparison of peak linear accelerations (PLA) by impact location and speed

1. The Outdoor Foundation (2016) Outdoor Participation Report.
2. Chou DW, Kshirsagar R, Liang J (2021) Head and neck injuries from rock climbing: A query of the National Electronic Injury Surveillance System. Ann Otol Rhinol Laryngol 130: 18-23.
3. European Committee for Standardization (2012) Mountaineering equipment – Helmets for mountaineers – Safety requirements and test methods. EN 12492:2012: E.
4. Mertz HJ, Irwin AL, Prasad P (2003) Biomechanical and scaling bases for frontal and side impact injury assessment reference values. Stapp Car Crash J 47: 155-188.
5. Safety Standard for Bicycle Helmets, 16 C.F.R. § 1203 (2021).
6. BOREO – Helmets, Petzl USA. Available online: https://www.petzl.com/US/en/Sport/Helmets/BOREO (accessed on 30 August 2021).

Corresponding author email: mbegonia@vt.edu