Virginia Tech Helmet Lab
120 Kelly Hall, Blacksburg, Virginia 24061
rowson@vt.edu

Virginia Tech Hockey Helmet Ratings Memorandum

Steve Rowson, Mark Begonia, Bethany Rowson, and Stefan Duma
Helmet Lab, Virginia Tech

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This memorandum serves to reiterate the goals of the Virginia Tech Helmet Ratings,[1] discuss the hockey helmet ratings, and announce an update to the exposure weightings and star thresholds used to rate hockey helmets.

Helmet Ratings Purpose

The Virginia Tech Helmet Ratings serve as an independent and objective resource that enables consumers to make informed purchasing decisions about relative helmet performance. All helmets included in the ratings pass minimum safety standards, ensuring an adequately low risk of severe or fatal head injury during impacts simulated during standards testing. Although all helmets pass their respective standards, notable differences in their ability to manage impact energy exist. Our helmet ratings aim to highlight these differences in the context of concussion risk for safety-oriented consumers.

We test each helmet through a sport-specific impact series and then combine the results into an overall helmet impact performance value. Finally, we categorize the helmet performance values within each sport into a star rating, varying from 0 to 5 stars. The star rating intends to aid consumers in interpreting the impact data and aligns with current best practices for safety evaluations.

For consumers, our ratings intend to highlight differences in helmet performance. For helmet manufacturers, our test methods and ratings intend to provide design criteria for reducing injury risk.

Hockey Helmet Ratings

We released hockey helmet ratings in 2014.[2] Using the hockey head impact exposure data available at the time, we determined generalized head impact conditions. Then, we mapped them to laboratory test conditions that included four impact locations and three impact energies. Each laboratory test condition was assigned an exposure weighting based on how often hockey players would see similar impacts during a season. Linear and rotational head acceleration are measured

[1] www.helmet.beam.vt.edu

[2] Rowson B, Rowson S, Duma SM. Hockey STAR: a methodology for assessing the biomechanical performance of hockey helmets. Annals of Biomedical Engineering. 2015 Oct; 43(10):2429-43.

for each test and related to concussion risk.[3] We compute an overall helmet performance score (STAR value) by multiplying each test's exposure weighting and concussion risk and then sum the products for each test condition. The score indicates how many concussions the average person would sustain if they experienced the impact exposure modeled in the lab.

Our initial rating release included 32 helmets. Only one helmet was rated with three stars and six helmets were rated with two stars. No helmet received a 4- or 5-star rating. We set the star rating thresholds with two goals in mind. First, we aimed to differentiate performance between helmets for consumers. The best performing helmets at that time were highlighted with 3- and 2- star ratings. Our second goal was to provide manufacturers with a performance target. Therefore, we set threshold requirements for 4- and 5-star ratings.

The hockey helmets struggled with the high energy impact test at all locations, with average accelerations of 228 g and 9599 rad/s^2 for all currently rated helmets. The medium energy impacts produced average accelerations of 111 g and 5479 rad/s^2. To put these values in perspective, the same high energy impacts on football helmets generate accelerations similar to those measured during medium energy impacts to hockey helmets. Given that a hockey player can experience these high energy impacts on rigid surfaces, such as the ice, we characterized these performance levels as an area for hockey helmets to improve.

Unfortunately, the hockey helmet manufacturers have not used the ratings to improve helmet performance like other sporting helmet manufacturers have.[4] Since our initial hockey helmet ratings, we've rated 26 additional helmets, and only two have been rated with 5 or 4 stars. The 5-star helmet is not widely available. Given the lack of buy-in from manufacturers, we are refocusing the ratings to identify differences between helmets better. It would better serve consumers to highlight the broad range of performance in existing helmets rather than compressing the rating scale to leave room for future 5-star helmets that might never come with the existing scale.

Hockey Helmet Ratings Update

We are announcing two major changes to the hockey helmet ratings: updating the exposure weighting and rescaling the star rating thresholds. The exposure weightings have been updated to align with our current evaluation philosophy, ensuring no impact locations are overly or negligibly influential. Impact energy weights have also been modified to emphasize performance at concussive levels. In addition, we are rescaling the star thresholds to identify differences within existing hockey helmets better using a 5-star scale.

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[3] Rowson S, Duma SM. Brain injury prediction: assessing the combined probability of concussion using linear and rotational head acceleration. Annals of Biomedical Engineering. 2013 May; 41(5):873-82.

[4] For example, when we first released football helmet ratings, only 1 helmet was rated with 5 stars but now manufacturers design helmets to achieve that ratings. There are 24 5-star helmets on the current varsity football helmet ratings.

Exposure Weightings

The side impact location accounts for 38% of the total performance score in the existing hockey helmet ratings, while the back only accounts for 18% (Table 1). Our testing philosophy considers all impact locations equally important, given that a helmet should protect regardless of where it is struck. If one location did not contribute much to the overall performance score, that location could be neglected during design. Even with high risk values at that location, the helmet could still have a good performance score if it were underweighted. Conversely, if one location contributed much more than others to the overall performance score, that location could be singularly enhanced relative to others. As a result, the helmet could have a rating that does not describe overall performance. Differences in the relative weighting between locations arise from varied force directions at each location. For example, impact force might be directed through the head's center of gravity (CG) at one location, away from the CG at another, and some forces might be directed in line with the neck and others not. Linear and rotational acceleration magnitudes vary with force direction.

On average, the high-energy impacts account for 49% of the total performance score in the existing hockey helmet ratings. Most helmets produce accelerations associated with 100% concussion risk in high-energy conditions. Only one helmet has excelled at managing this energy level. The low-energy conditions account for 12% of the total score, and the medium energy does 39%. A logical modification is to increase the weight of the medium-energy conditions that produce accelerations in the concussive range and decrease the weight of the high-energy conditions. This change would better highlight differences among existing helmets in their ability to reduce concussion risk.

Table 1: The average overall performance score proportion that each impact location and energy account for between the 58 hockey helmets we've tested.

Location	Low	Medium	High	Total
Back	3%	5%	10%	18%
Front	1%	7%	13%	20%
Side	7%	18%	13%	38%
Top	2%	10%	12%	24%
Total	12%	39%	49%	

We have updated the exposure weightings that are used to determine the overall performance score (STAR value). The weightings were optimized to meet two criteria: 1) each location should contribute equally to the overall performance score on average, and 2) the medium-energy tests should contribute the most to the overall performance score. The medium energy was set to account for 2/3 of the overall performance score on average. The low and high energies were set to account for 1/6 of the overall performance score each. Weighting values were determined by computing the average linear and rotational accelerations for each impact condition across locations. We then computed risks for each impact condition and solved for scaling factors that would result in the aforementioned location and energy contributions to the overall performance

score. Table 2 shows the updated exposure weighting values that are now used to compute the overall scores.

Table 2: Exposure weightings for each location and energy tested in the hockey helmet evaluation protocol. A total of 55.113 impacts are modeled. For the average helmet, these weightings result in each location contributing 25% to the overall score and redistribute score influence between impact energies (low: 1/6, medium: 2/3, high: 1/6).

Location	Low	Medium	High
Back	11.027	1.244	0.051
Front	22.150	0.759	0.044
Side	3.441	0.317	0.042
Top	15.474	0.519	0.045

Rating Thresholds

In the existing hockey helmet ratings, 91% of the helmets are rated with 2 stars or less. This distribution of ratings effectively makes it a 3-star scale. The bar for 5 stars was set so high that only one helmet has achieved the top rating in 7 years. While we still believe that hockey helmet impact performance should meet these levels, we have rescaled the thresholds using the updated exposure weighting to compare helmet performance on a 5-star scale for consumers.

After the exposure weighting update, the average score (STAR value) across existing helmets is 1.0. A 5-star rating threshold was set to a 50% reduction relative to the average helmet, and then each subsequent rating threshold was set in increments of 50% more risk from the 5-star threshold (Table 3).

Table 3: New star rating thresholds for hockey helmets based on the updated exposure weightings.

Rating	Score Threshold	Context
5	< 0.50	50% reduction from average existing helmet
4	< 0.75	50% worse performance than 5-star threshold
3	< 1.00	100% worse performance than 5-star threshold
2	< 1.25	150% worse performance than 5-star threshold
1	>= 1.25	lowest performing group

Summary

We updated our hockey helmet ratings to better highlight differences in impact performance between helmets, most notably at concussive levels. The updated ratings also consider each impact location equally influential to the overall score. With the new weightings and star-rating thresholds, we highlight the performance of 7 existing helmets with a 5-star rating and 14 with a 4-star rating (Figure 1). Ultimately, this will provide consumers with an improved tool to make informed decisions when purchasing new hockey helmets.

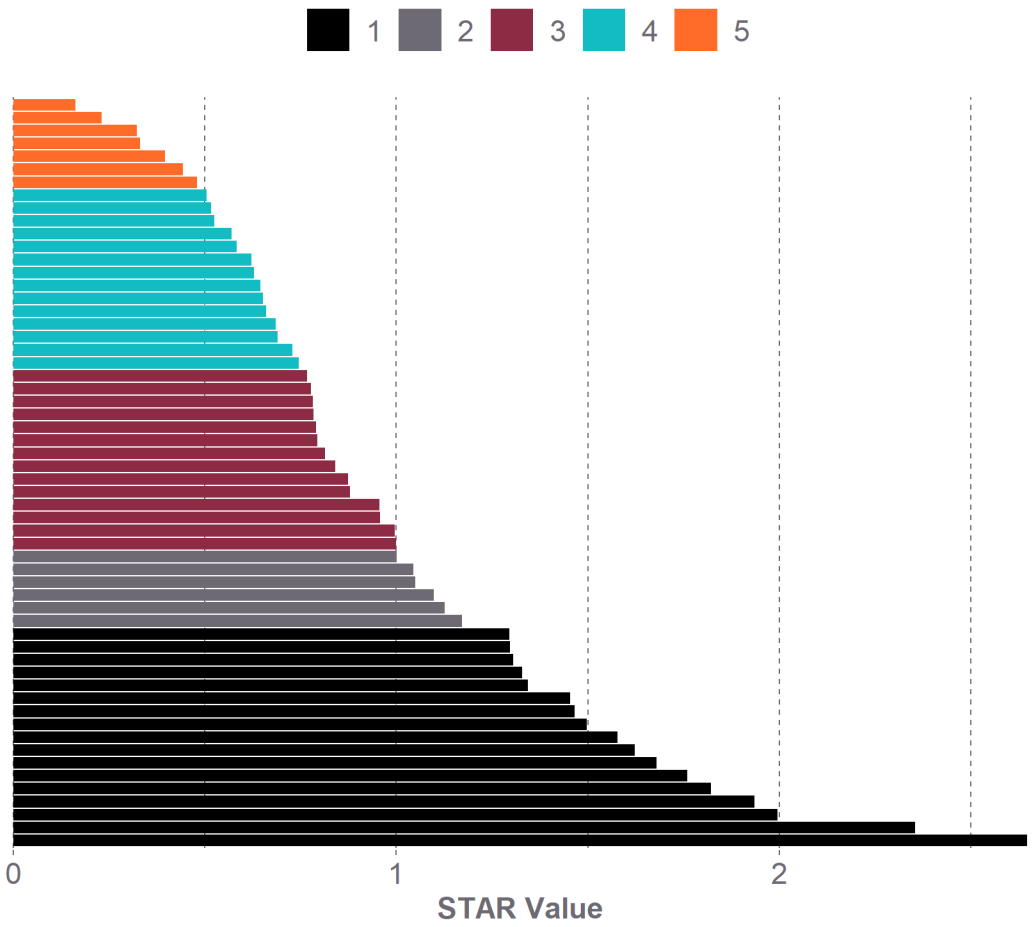

Figure 1: Rescaled STAR values for currently rated hockey helmets, ordered best (top) to worst (bottom). Each bar represents one helmet model and its fill color indicates its star rating.