# The STAR Rating System for Football Helmets

## STAR = Summation of Tests for the Analysis of Risk

The STAR value for each helmet model is derived from 120 impacts on 3 new helmets using the following equation and methodology:

$$STAR = \sum_{L=1}^{4} \left( \sum_{H=1}^{6} E(L,H) \bullet R(a) \right)$$

*Using NOCSAE style tests with the following nomenclature:*

L = helmet location, four total: front, top, side (combined), and rear
H = drop height, six total: 60”, 48”, 36”, 24”, 12”, and lowest
E = exposure (function of drop height), number of impacts at that drop height for that location a player may experience in one year
R = Concussion injury risk (function of peak acceleration)
*a* = peak resultant acceleration

$$STAR = \sum_{Location=1}^{4} \left( \sum_{Height=1}^{6} Exposure(L,H) \bullet Risk(a) \right)$$

### The STAR value represents a **Generalized Concussion Incidence**

In other words, the STAR value is the number of concussions that one player may experience through the duration of playing one complete season with a specific helmet. So, the lower the STAR value, the better the helmet at reducing the risk of concussion, and subsequently the higher ‘# stars’ in the rating system.

**Limitations**

1) Any player in any sport can sustain a head injury with even the very best head protection.
2) This analysis is based on data trends and probabilities, and therefore a specific person’s risk may vary. This variation is likely dominated by genetic differences, health history, and impact factors such as muscle activation.
3) The exposure is for a starting competitive collegiate football player for a full season of practices and games; however, it can be scaled for any given exposure in high school or NFL.
4) All head impacts result in both linear and rotational accelerations. This methodology utilizes only linear acceleration as currently there is substantial data on linear accelerations relating to concussion risk. Moreover, linear and rotational accelerations are highly correlated, and in general lowering linear will lower rotational. As more data become available for rotational accelerations associated with concussions, this methodology could be modified to include them.

# Adult Football Helmet Evaluation Methodology

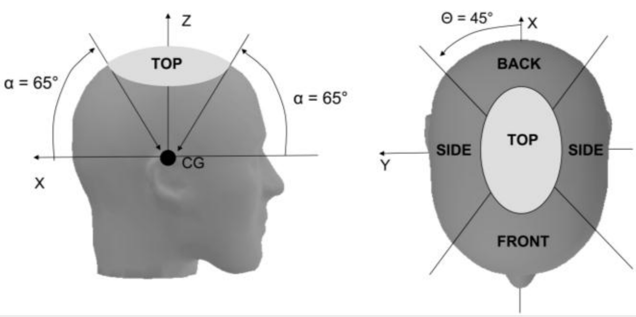
*May 1, 2012*



**Exposure**

$$STAR = \sum_{L=1}^{4}\left(\sum_{H=1}^{6} E(h) \bullet R(a)\right)$$

## Exposure by Location:

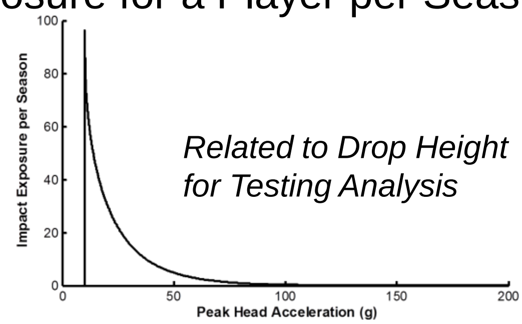



| | VT Data | Mihalik et al. 2007 |
|---|---|---|
| **Front** | 34.7% | 35.9% |
| **Rear** | 31.9% | 30.9% |
| **Side** | 16.3% | 14.4% |
| **Top** | 17.1% | 18.8% |

## Exposure for a Player per Season:

| Study | Impacts per Season | Subjects |
|---|---|---|
| VT Data (Crisco et al. 2010) | 1000 | Collegiate |
| Guskiewicz et al. 2007 | 950 | Collegiate |
| Schnebel et al. 2007 | 1115 | Collegiate and High School |
| Broglio et al. 2009 | 565 | High School |

## Exposure for a Player per Season per Location:




| | Percent of Impacts | Number of Impacts |
|---|---|---|
| **Front** | 34.7% | 347 |
| **Rear** | 31.9% | 319 |
| **Side** | 16.3% | 163 |
| **Top** | 17.1% | 171 |
| **Total** | 100% | 1000 |

References:


Broglio, S. P., Sosnoff, J. J., Shin, S., He, X., Alcaraz, C., and Zimmerman, J., 2009, "Head Impacts During High School Football: A Biomechanical Assessment," J Athl Train, 44(4), pp. 342-9.

Crisco, J. J., Fiore, R., Beckwith, J. G., Chu, J. J., Brolinson, P. G., Duma, S., Mcallister, T. W., Duhaime, A. C., and Greenwald, R. M., 2010, "Frequency and Location of Head Impact Exposures in Individual Collegiate Football Players," J Athl Train, 45(6), pp. 549-59.

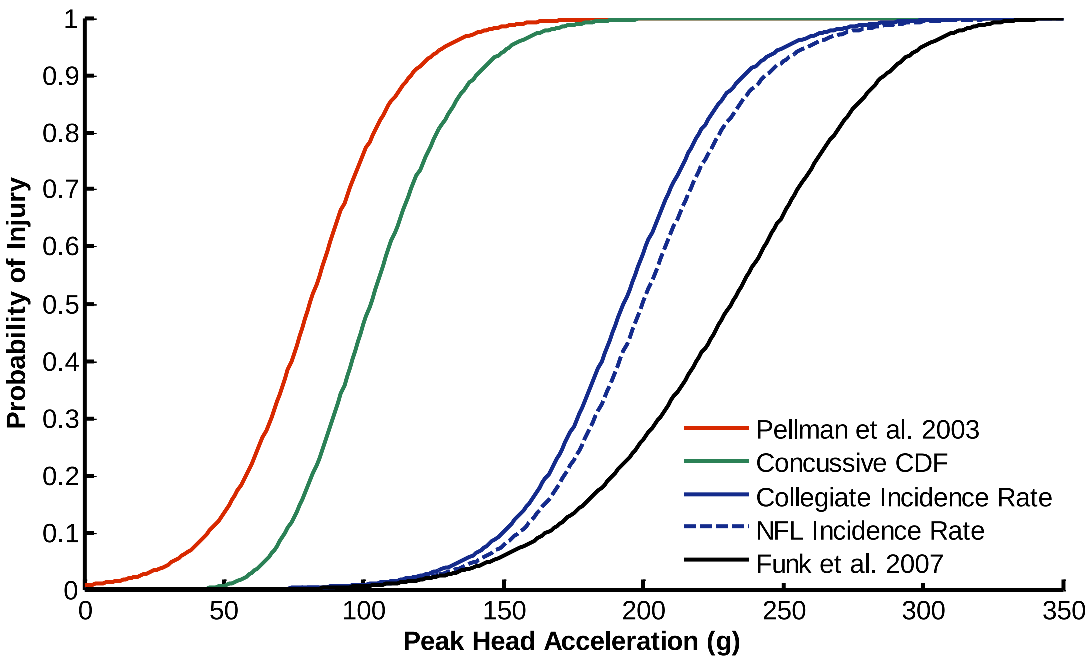
Guskiewicz, K. M., Mihalik, J. P., Shankar, V., Marshall, S. W., Crowell, D. H., Oliaro, S. M., Ciocca, M. F., and Hooker, D. N., 2007, "Measurement of Head Impacts in Collegiate Football Players: Relationship between Head Impact Biomechanics and Acute Clinical Outcome after Concussion," Neurosurgery, 61(6), pp. 1244-53.

Schnebel, B., Gwin, J. T., Anderson, S., and Gatlin, R., 2007, "In Vivo Study of Head Impacts in Football: A Comparison of National Collegiate Athletic Association Division I Versus High School Impacts," Neurosurgery, 60(3), pp. 490-5; discussion 495-6.

Risk

$$STAR = \sum_{L=1}^{4}\left(\sum_{H=1}^{6} E(h) \bullet R(a)\right)$$

Concussion Risk R(a) = Collegiate Incidence Rate Curve




$$Risk = \frac{1}{1+e^{-(\alpha x+\beta)}}$$

Where
x = peak resultant linear acceleration in g
α = 0.0508
β =-9.8047

References:

Guskiewicz, K. M., Mihalik, J. P., Shankar, V., Marshall, S. W., Crowell, D. H., Oliaro, S. M., Ciocca, M. F., and Hooker, D. N., 2007, "Measurement of Head Impacts in Collegiate Football Players: Relationship between Head Impact Biomechanics and Acute Clinical Outcome after Concussion," Neurosurgery, 61(6), pp. 1244-53.

Broglio, S. P., Schnebel, B., Sosnoff, J. J., Shin, S., Fend, X., He, X., and Zimmerman, J., 2010, "Biomechanical Properties of Concussions in High School Football," Med Sci Sports Exerc, 42(11), pp. 2064-71.

Funk, J. R., Duma, S. M., Manoogian, S. J., and Rowson, S., 2007, "Biomechanical Risk Estimates for Mild Traumatic Brain Injury," Annual Proceedings of the Association for the Advancement of Automotive Medicine, 51, pp. 343-61.

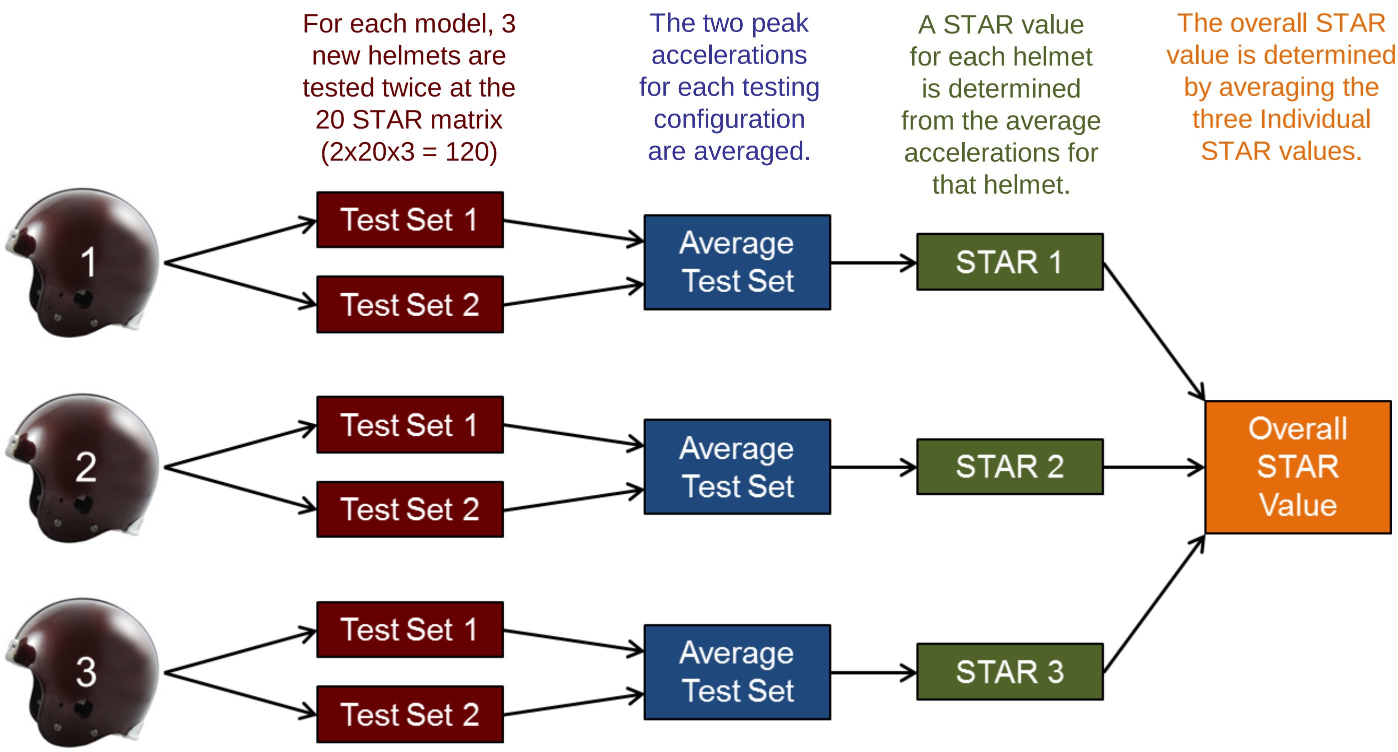
Pellman, E. J., Viano, D. C., Tucker, A. M., Casson, I. R., and Waeckerle, J. F., 2003, "Concussion in Professional Football: Reconstruction of Game Impacts and Injuries," Neurosurgery, 53(4), pp. 799-812; discussion 812-4.

# Summary STAR Calculation Worksheet

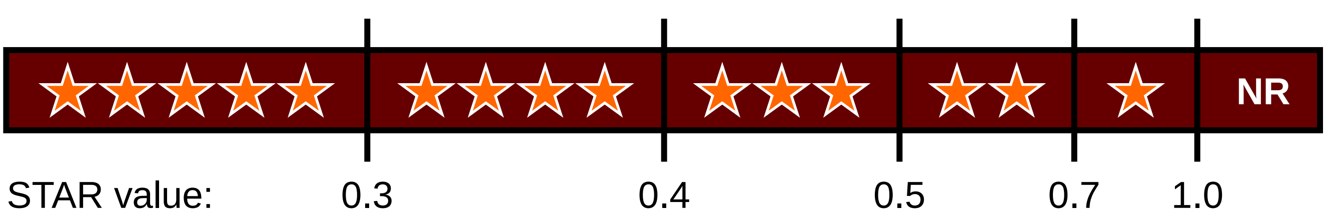
$$STAR = \sum_{L=1}^{4}\left(\sum_{H=1}^{6} E(L,H)\bullet R(a)\right)$$

| Impact Location | Drop Height | Peak G | Risk of Injury | Exposure per Season | Incidence per Season |
|---|---|---|---|---|---|
| **Front** | **Impacts < 19 g** | ----- | 0.0000 | 164 | 0.00 |
| **Front** | **12 in** | Average of 2 Tests | From Risk(a) | 138 | *Exp * Risk* |
| **Front** | **24 in** | Average of 2 Tests | From Risk(a) | 31 | *Exp * Risk* |
| **Front** | **36 in** | Average of 2 Tests | From Risk(a) | 10 | *Exp * Risk* |
| **Front** | **48 in** | Average of 2 Tests | From Risk(a) | 3 | *Exp * Risk* |
| **Front** | **60 in** | Average of 2 Tests | From Risk(a) | 1 | *Exp * Risk* |
| | | | | | |
| **Side** | **Impacts < 19 g** | ----- | 0.0000 | 81 | 0.00 |
| **Side** | **12 in** | Average of 2 Tests | From Risk(a) | 75 | *Exp * Risk* |
| **Side** | **24 in** | Average of 2 Tests | From Risk(a) | 4 | *Exp * Risk* |
| **Side** | **36 in** | Average of 2 Tests | From Risk(a) | 1 | *Exp * Risk* |
| **Side** | **48 in** | Average of 2 Tests | From Risk(a) | 1 | *Exp * Risk* |
| **Side** | **60 in** | Average of 2 Tests | From Risk(a) | 1 | *Exp * Risk* |
| | | | | | |
| **Rear** | **Impacts < 19 g** | ----- | 0.0000 | 139 | 0.00 |
| **Rear** | **12 in** | Average of 2 Tests | From Risk(a) | 165 | *Exp * Risk* |
| **Rear** | **24 in** | Average of 2 Tests | From Risk(a) | 11 | *Exp * Risk* |
| **Rear** | **36 in** | Average of 2 Tests | From Risk(a) | 2 | *Exp * Risk* |
| **Rear** | **48 in** | Average of 2 Tests | From Risk(a) | 1 | *Exp * Risk* |
| **Rear** | **60 in** | Average of 2 Tests | From Risk(a) | 1 | *Exp * Risk* |
| | | | | | |
| **Top** | **Impacts < 19 g** | ----- | 0.0000 | 63 | 0.00 |
| **Top** | **12 in** | Average of 2 Tests | From Risk(a) | 85 | *Exp * Risk* |
| **Top** | **24 in** | Average of 2 Tests | From Risk(a) | 14 | *Exp * Risk* |
| **Top** | **36 in** | Average of 2 Tests | From Risk(a) | 5 | *Exp * Risk* |
| **Top** | **48 in** | Average of 2 Tests | From Risk(a) | 2 | *Exp * Risk* |
| **Top** | **60 in** | Average of 2 Tests | From Risk(a) | 2 | *Exp * Risk* |
| | | ***Total Head Impacts In One Season:*** | | ***1000*** | *Sum Incidence* |
| | | | | | ***STAR Value*** |

STAR Calculation Overview: The STAR value for each helmet model is derived from 120 impacts on 3 new helmets using the following equation and methodology:




STAR values were assigned a rating based on predetermined thresholds. These thresholds were determined based on a statistical analysis of the May 2011 STAR values. Star groupings are determined as follows:



Note for 2012 Helmet Ratings:

Football helmets from 2011 were not retested for the 2012 ratings. A series of system checks and control tests were performed to ensure that consistent results were obtained for previously evaluated helmet models. If a helmet model had undergone design changes that would affect the performance of the helmet, the manufacturer would have been required to notify NOCSAE of the changes.

Football helmet models that had been made available to consumers since the release of the May 2011 Virginia Tech Helmet Ratings™ were tested using identical methods to those used to evaluate the football helmets included in the May 2011 Virginia Tech Helmet Ratings™. The Virginia Tech Helmet Ratings™ were then updated to include the results from current and previous adult football helmet models.

A manuscript detailing the derivation of the STAR methodology has been peer reviewed and published by the *Annals of Biomedical Engineering*:

Rowson S and Duma SM, "Development of the STAR Evaluation System for Football Helmets: Integrating Player Head Impact Exposure and Risk of Concussion," Annals of Biomedical Engineering, 39(8): 2130-2140.

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