Evaluation of American Football Helmet Impact Performance From 1880s to 2020s

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Abstract

Abstract: The purpose of this research is to study the impact performance of American football helmets spanning from the late 1800's through the early 2020's. Helmet technology has evolved significantly from knit caps worn in the late 1800's to the iconic leather skull cap styles in the early 1900's to plastic shells with suspension-style liners in the mid 1900's to the modern helmets worn today. Helmets today feature soft shells, advanced liner technology, and components optimized with High Performance Computing (HPC) to minimize head and brain damage. While the technology used in football helmets has evolved significantly, we seek to understand how these changes influence the impact attenuation over the decades. The twin-wire drop tower at the state-of-the-art Helmet Performance Lab (HPL) was used to evaluate a total of 17 helmets using the NOCSAE [1] positions front, rear, side, and top from a drop height of 1 foot (2.5 m/s). For each helmet, the total mass, peak acceleration (Peak-G), Severity Index (SI), and Head Injury Criterion (HIC) are recorded to evaluate system response. Preliminary experimental results show that the 2000-2010 helmets had the lowest results in the front position, the 1950-1960 helmets performed best in the rear and side positions, and the 1970-1980 helmets were best in the top position.

Research Question

Research Question: The research objective is to apply NOCSAE testing methods [1] for American football helmets to investigate the differences in system response from the 1880s to the 2020s

Methods

Methods: The twin-wire drop tower (pictured right) is used to evaluate helmet impact performance according to the NOCSAE [1] football helmet standards. Football helmets are typically tested in six different orientations, however, only four were selected for this study. The four selected orientations include: front, side, top, and rear. We tested 17 helmet samples from the late 1800's to 2020's in each position from a drop height of one foot to achieve an impact velocity of 2.5 m/s. The recorded impact time history was used to calculate peak-g values for each impact. A peak-g value above 105 ± 27 g is believed to cause a concussion [2].

Peak-G Values of Helmets from 1880's to 2020's

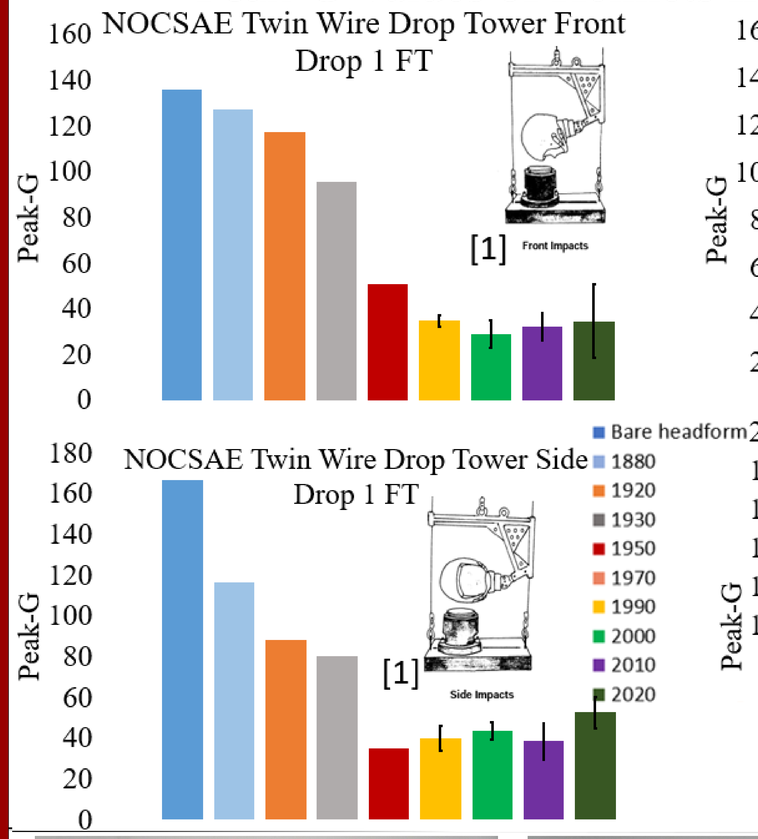

Photo by [William Dean] Reproduction cap – 1920

Photo by [William Dean] Riddell VRS4 - 1990

Photo by [William Dean] Twin-wire drop tower

Photo by [William Dean] Spalding Gardite - 1950

Photo by [William Dean] Schutt F7 VTD - 2020

Results and Conclusion

Results:

Test Position	Best Performing Decade	Lowest Value (Peak-G)
Front	2000s	29.14
Top	1970s	34.17
Side	1950s	35.04
Rear	1950s	26.21

Table by [William Dean]

Conclusions: Test results show that in the front NOCSAE test position, 2000-2010s helmets had the lowest values. In the rear and side positions, the 1950-1960s helmets performed the best. For the top position, the best was the helmets from the 1970-1980s. While an impact of 2.5 m/s may seem small, most impacts in the sport of American football happen at lower velocities. Future work must be done to understand the correlation and performance of the earlier produced helmets at higher velocities. The older helmets may not be able to withstand the higher end of velocities impacts in football. The more recently produced football helmets have been focused on reducing the brain damage at higher velocities.

Future Work

1. Testing the helmets at 2 and 3 feet on the NOCSAE twin-wire drop tower.
2. The helmets tested on a pneumatic linear impactor (pictured below) at 5.5m/s, 7.4 m/s and 9.3 m/s.

Acknowledgments

- Liberty University School of Engineering Helmet Performance Lab (HPL) at the Center for Engineering Research and Education (CERE) for the utilization of their NOCSAE twin-wire drop tower
- Dr. Mark for his ideas and providing access to helmets
- Tate Fonville for his daily guidance and support

Key References

[1] National Operating Committee on Standards for Athletic Equipment. (2018a), "Standard Test Method and Equipment Used in Evaluating the Performance Characteristics of Headgear/Equipment" NOCSAE Document 001-17m-17b

[2] Rowson, Steven, and Stefan M. Duma. "Development of the STAR evaluation system for football helmets: integrating player head impact exposure and risk of concussion." *Annals of biomedical engineering* 39, no. 8 (2011): 2130-2140