Design of Player Specific American Football Helmets to Protect the Brain

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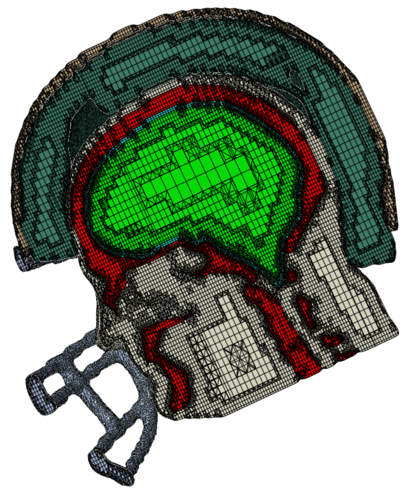
Abstract

Abstract: The objective of this research is to investigate the relationship between mechanical action and brain damage to design player-specific American football helmets using High Performance Computing (HPC), Finite Element (FE) simulations, and experiments. We created a high-resolution FE head mesh from MRI scan data with segmented scalp, skull, Cerebral Spinal Fluid (CSF), and brain. We use a multiscale Internal State Variable (ISV) model for the brain that will be calibrated to experimental data and capable of predicting brain damage. Varying strain rate experiments from monotonic (0.1/sec; Instron), to intermediate (200/sec; Hopkinson bar) were used to characterize a selection of conventional and auxetic polyurethane foams. The foams were used in a FE simulation study to select the optimal layering pattern that maximizes energy absorption and minimizes mechanical action and brain damage. The best functional gradient design was incorporated into a prototype American football helmet and tested at the newly developed Helmet Performance Lab (HPL) at the Liberty University (LU) Center for Engineering Research and Education (CERE). The HPL at LU is fully equipped to conduct the National Football League (NFL) and National Operating Committee on Standards for Athletic Equipment (NOCSAE) standard testing. Our prototype passed all NOCSAE standards and showed a 15% improvement compared to two of the top performing helmets from 2020. This process may be repeated using a different set of boundary conditions to design protective sport helmets for other sports including hockey, lacrosse, and equestrian

Research Question

Research Question: Can a new football helmet prevent brain injury considering mechanical action and brain damage levels using High Performance Computing (HPC), Finite Element (FE) simulations, and experiments?

Methods



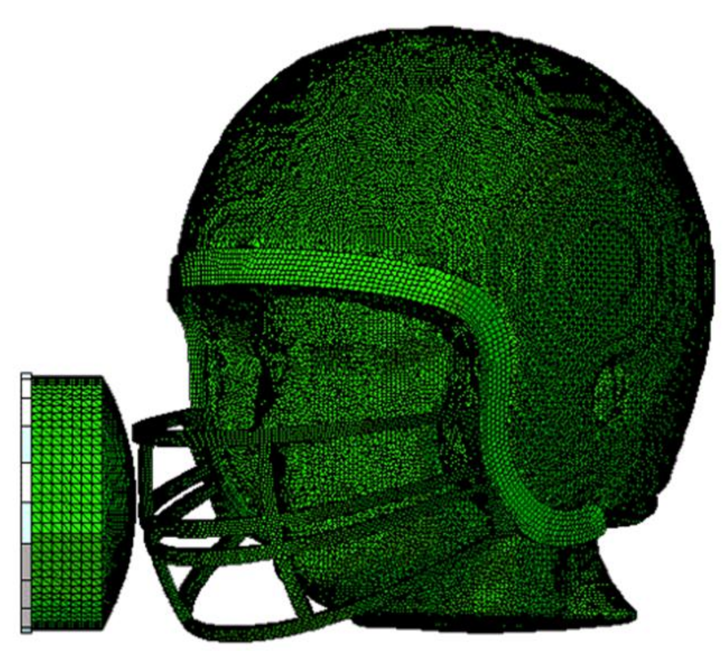
1. High Performance Computing is used to simulate real-world impacts with different helmet designs in order to better understand how the brain responds to mechanical loads

2. The optimal liner configurations are incorporated into a helmet prototype and

3. Tested using the NFL and NOCSAE standard tests at the Helmet Performance Lab (HPL) at the Center for Engineering Research and Education (CERE)

Helmet research and development efforts to protect the brain

Thousands of helmet design alternatives may be evaluated using the Finite Element (FE) mesh. Optimal designs are then modeled using Computer Aided Design (CAD) and then built as a prototype for testing.

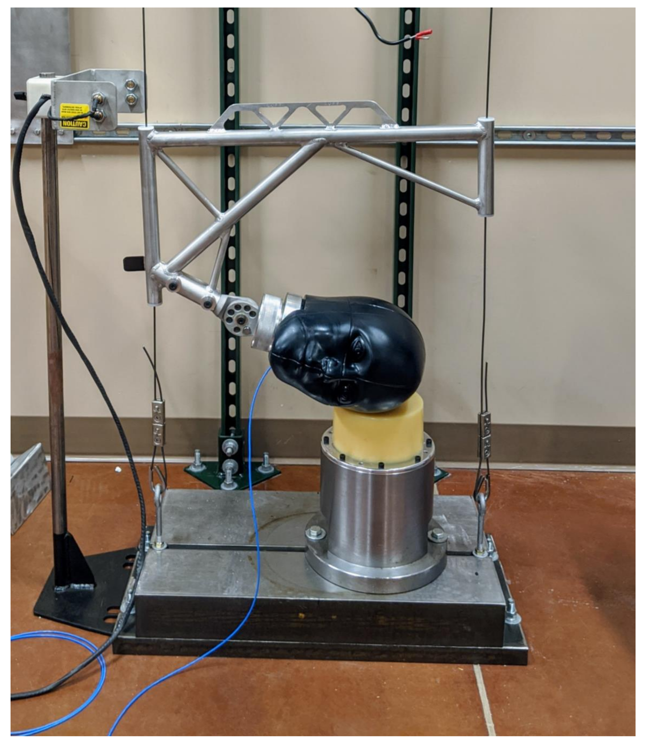


FE Mesh

CAD Model

Prototype

A pneumatic linear impactor is used to evaluate a helmet's ability to mitigate rotational accelerations using the National Football League (NFL) standards

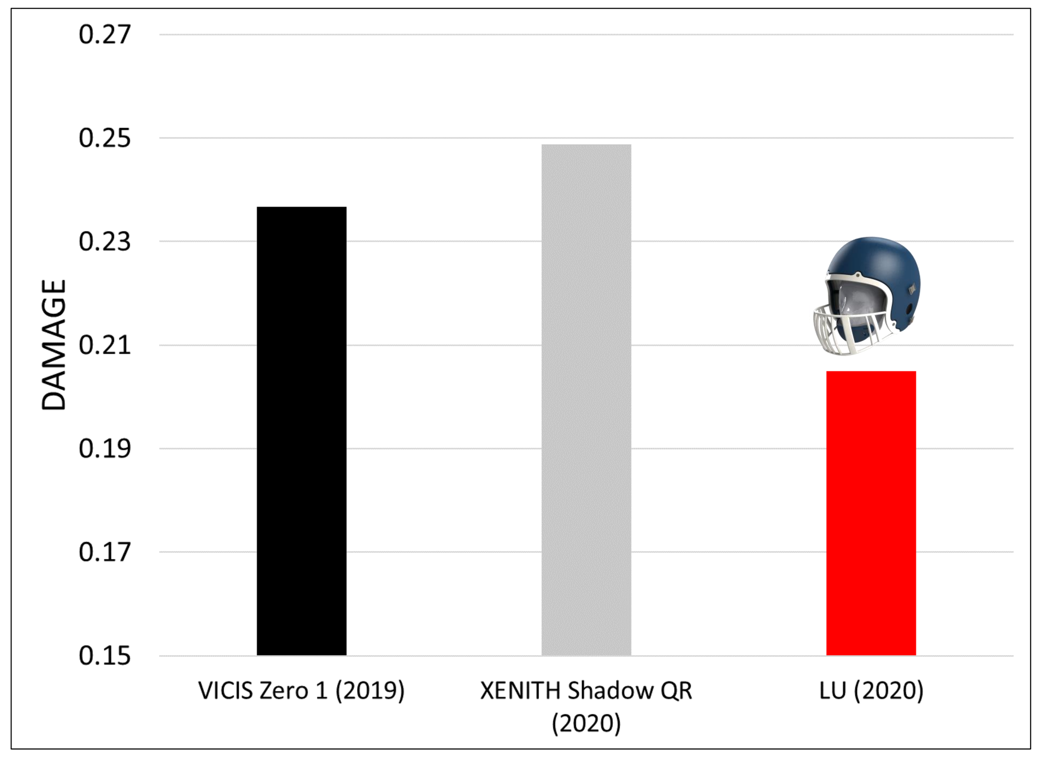


NOCSAE Twin Wire Drop Tower

Pneumatic Linear Impactor

Results and/or Conclusion

Results: Preliminary test results show 15% improvement over two of the top performing helmets currently on the market.



Conclusions: The results from this study are a clear indication that new football helmets may be designed using HPC, FE simulations, and laboratory experiments that improve safety over top performing competitors. Modeling and building a prototype helmet is costly and time consuming; therefore, leveraging HPC is vital to be able to design helmets that meet the demands of different positions. Additionally, using the multiscale ISV model for the brain, we were able to identify designs that minimized mechanical action and brain damage. This process can be reiterated to create designs that meet position-specific and skill-specific demands for American football and similar contact sports like hockey and lacrosse.

Future Work

1. Reiterate this process to design, build, and test a collection of position-specific helmets using data collected by the NFL and then use with the Israeli NFL team in collaboration with Ariel University
2. Submit the optimal helmet design to the NFL Helmet Challenge
3. Apply this technology to develop helmets for other contact sports

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NFL