

Study aims to prevent deadly sports injury in young athletes

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At an Arizona baseball diamond 10 years ago, a 13-year-old baseball player turned to bunt a ball that instead struck his chest. Taking two steps towards first base, he collapsed and died from commotio cordis, the second leading cause of sudden cardiac death in young athletes.

It's an outcome Grant Dickey, a Ph.D. student in biomedical engineering, is hoping to change. Dickey recently published findings from his master's research that provides new metrics for testing baseball chest protectors and identifies the most vulnerable impact locations over the chest that may result in commotio cordis.

Rare but fatal

"Commotio cordis is very rare, but when it happens, it's very often fatal," Dickey said. "You can imagine the impact on the players and the families in these situations. It's incredibly tragic."

The phenomenon results from a small, blunt object impacting the chest at speeds of approximately 40 mph during a vulnerable period of the cardiac cycle called the T-wave. The [heart](#) goes into ventricular fibrillation, and quivers, unable to pump blood throughout the body and to the brain.

Immediate use of an external automatic defibrillator (AED) may shock the heart back into rhythm. Without such intervention, the injured child is likely to die.

The United States commotio cordis registry in Minneapolis has confirmed more than 200 cases worldwide since 1996. Fewer than 20 percent of those affected survived. However, the true number of deaths is unknown because of underreporting and misclassification.

Dickey said this rare sudden-death mechanism most commonly affects young children playing baseball, yet current baseball chest protectors fail to prevent commotio cordis.

"Children have a much weaker and narrow chest cage, making them more vulnerable to these [impacts](#) over the heart," he said.

Dickey, who has loved sports since childhood, knows the best defense protects vulnerable areas.

Supervised by Canada Research Chair and Western engineering professor Haojie Mao, Dickey's master's research looked to develop new commotio cordis injury metrics to create a more accurate prediction for chest protector effectiveness. His work also analyzed the current injury metrics used by the National Operating Committee on Standards for Athletic Equipment (NOCSAE). He then identified potentially vulnerable impact locations currently ignored by safety regulations and commercially available chest protectors.

Previous commotio cordis investigations studied the impact of baseballs using swine hearts and analyzing heart pressure. Dickey's team took a novel approach, through computational modeling.

Their first study aimed to unravel the connection between chest force and rib deformation to [left ventricle](#) strain pressure.

"We believed there was a unique opportunity to address the void in the literature, and introduce new key concepts," Dickey said. "One was

analyzing left ventricle strain, which previously wasn't studied. The other was a rib deformation injury metric we introduced, thinking it could be beneficial based on our studies and results."

Adopting a computational model that represents the anatomical features and biomechanical properties of a 10-year-old human, his team replicated commotio cordis instances by simulating 128 different baseball impacts to the chest. They adapted speeds and varying degrees of baseball stiffness.

"The ribs lay over the chest as a protective case for the organs inside," Dickey said. "In our study, we found ribs three, four and five directly lay over the heart, and in particular, the left ventricle."

Studying how the [ribs](#) deformed in correlation to the increase in the left ventricle strain and left ventricle pressure, Dickey found the higher the deformation, the higher the increase in strain and pressure values.

While it's been previously suggested softer baseballs may prevent commotio cordis, Dickey's findings indicated the stiffness of the baseball made no difference in left ventricle strain or pressure.

Vulnerable impact locations

Dickey's second study created heat maps over the chest to identify the most vulnerable positions.

"We found impacts slightly above and off to the side of the heart, on the cusp of the outside of the heart's silhouette, produced very high left ventricle strain," Dickey said. "When the baseball impacted the chest, just above the heart, it was causing the rib cage to push against the left ventricle of the heart and causing a high strain value."

Current chest protectors offer general padding throughout. Dickey sees an opportunity to increase the padding over and above the cardiac silhouette to prevent damage to those potentially vulnerable locations.

His master's thesis included preliminary studies of a circular pad design that allowed his team to analyze its ability to reduce strain and pressure in the left ventricle of the heart.

Next steps

Dickey is hoping to advance his work as he pursues his Ph.D. in biomedical engineering. He's looking to conduct future simulations studying the impact of hockey pucks and lacrosse balls, and to move his work beyond simulation testing to human cardiac tissue.

His group is also hoping to approach athletic chest equipment manufacturers as potential collaborators. "That would be a great opportunity not only for our laboratory, but for companies who just want to improve their product and safety," Dickey said.

Mao applauds Dickey's novel work as the first investigator to employ computational modeling to study commotio cordis biomechanics.

"Grant's research to understand commotio cordis is relevant to every kid playing sports such as [baseball](#)," Mao said. "Though he is still in the Ph.D. program, Grant could be justified among a very few of the world's top experts in understanding the commotio cordis problem."

More information: Grant J. Dickey et al, Identifying Vulnerable Impact Locations to Reduce the Occurrence of Deadly Commotio Cordis Events in Children's Baseball: A Computational Approach, *Journal of Biomechanical Engineering* (2021). [DOI: 10.1115/1.4052886](https://doi.org/10.1115/1.4052886)

Grant J. Dickey et al, Developing commotio cordis injury metrics for baseball safety: unravelling the connection between chest force and rib deformation to left ventricle strain and pressure, *Computer Methods in Biomechanics and Biomedical Engineering* (2021). DOI: [10.1080/10255842.2021.1948022](https://doi.org/10.1080/10255842.2021.1948022)

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