Risk, Reform, and Innovation: The Impact of Major Accidents on Sports Safety Technologies

A Research Paper submitted to the Department of Engineering and Society

Presented to the Faculty of the School of Engineering and Applied Science

University of Virginia • Charlottesville, VA

In Partial Fulfillment of the Requirements for the Degree

Bachelor of Science, School of Engineering

Sydney A. Bakir

Spring 2025

On my honor as a University of Virginia student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

ADVISOR

Prof. Kent A. Wayland, Department of Engineering and Society

Introduction

Sports have always involved risk, but modern engineering, medicine, and biomechanics have produced tools that drastically reduce harm. Yet these protective technologies are often implemented only after tragedy strikes. From NASCAR to the NFL, life-saving innovations have remained optional or sidelined until a fatal crash, lawsuit, or overwhelming pressure forced action—even when scientific evidence supported their effectiveness.

This paper investigates a critical question: What factors delay the mandation of protective sports gear, and what finally overcomes this delay? While it may be tempting to blame oversight or uncertainty, research shows that cultural resistance, institutional inertia, aesthetic concerns, and legal fears contribute to a broader pattern of delayed reform.

Understanding these delays matters—not just for athletes but for public policy. Like military training, aviation, or industrial labor, sports are high-risk domains where safety decisions must balance performance, tradition, and public perception. Sports provide a powerful lens to study why protective gear—even when validated—faces resistance, and what ultimately drives institutions to mandate change.

This study draws on the reactionary model of safety governance, showing how reforms are not driven by evidence alone but by tipping points: tragedy, litigation, or reputational crisis. Through case studies in motorsports, hockey, football, and Olympic events, this paper explores the forces delaying mandatory protective gear and the catalysts that finally compel adoption.

Background & Context

Sociotechnical Situation: The Complexities of Safety Policy in Sports

Adopting safety technologies in sports occurs within a complex sociotechnical system—where technical feasibility is only one part of a much larger equation. Even when scientific evidence confirms that equipment can prevent serious injury, that evidence alone is rarely enough to prompt policy change. Instead, decisions are shaped by a web of interacting forces: athletes, institutions, media, sponsors, and fans all influence whether safety reforms move forward—or stall.

Athletes are often the first point of resistance. In sports rooted in toughness and tradition, new equipment can threaten performance or identity. Helmets might limit vision, neck guards restrict mobility, or cockpit devices feel claustrophobic. Even when risks are understood, elite athletes often push back—especially if the gear is optional. In competitive environments, where fractions of a second matter, many resist anything that changes how the sport feels.

Institutions face a different kind of tension. While they are responsible for athlete safety, they are also accountable to sponsors, broadcasters, and fans. Mandating safety changes can imply that past policies were inadequate—opening the door to lawsuits or reputational damage. As a result, many organizations delay reform until tragedy strikes or until the public and legal risks of inaction outweigh the cost of change.

Public perception plays a decisive role as well. Fans and media often resist changes that alter the look or pace of a sport. Safety technologies that disrupt aesthetics or gameplay are frequently mocked. In the early 2000s, NASCAR fans dismissed head restraints as unnecessary; in Formula 1, the Halo device was derided as ugly. Even football's Guardian Cap, designed to reduce concussions, was labeled a symbol of softness. Social media has only amplified this backlash, turning minor dissent into dominant narratives.

These forces create a tightly coupled sociotechnical system that resists proactive reform. In sports, risk is not governed purely by science but by narrative, identity, and fear. These tensions explain why life-saving technologies are often adopted only after a loss becomes too public—or too tragic—to ignore.

This dynamic reflects the reactionary model of safety governance. To understand why this model persists, the following literature review explores the cultural, institutional, and legal factors that shape reform.

Literature Review: Risk, Resistance, and the Delayed Adoption of Safety Technologies

Researchers have identified a persistent pattern across sports medicine, injury prevention, and STS scholarship: safety regulations tend to follow catastrophe, not anticipate it. This reactionary pattern does not stem from a lack of innovation but from complex socio-cultural, institutional, and economic forces that delay the adoption of protective measures until a crisis occurs.

Athlete Resistance to Safety Innovations

One commonly cited barrier to early adoption is athlete resistance. Even when gear is scientifically validated, it is often viewed as uncomfortable, restrictive, or a threat to performance. Tjønndal and Wågan (2021) found that athletes across sports are less likely to wear protective equipment unless required, even when they acknowledge its benefits. The HANS device was available for over a decade before drivers accepted it, largely due to concerns about mobility and emergency egress (Gibson et al., 2013).

Similar pushback occurred with the Halo in Formula 1, which was criticized for impairing visibility and altering the open-cockpit design (Ludvigsen, 2023; Srinivasan &

Demirel, 2022). In hockey, neck protection has long been resisted due to discomfort and tradition—even after repeated injuries (Adams et al., 2016). These examples show how norms of toughness and autonomy can override evidence.

Institutional Inertia and Policy Hesitation

Governing bodies face a different set of pressures. While responsible for safety, they must also consider financial risk, brand identity, and legal exposure. Finch (2006) argues that policy change often stalls even when evidence is unmistakable due to institutional hesitancy and competing interests. Reform may signal past failure—opening the door to liability.

This was evident in the NFL's slow response to concussion research. Despite strong evidence of long-term brain injury, the league resisted action until a 2011 class-action lawsuit forced widespread policy change (Belson, 2013). NASCAR mandated the HANS device only after Dale Earnhardt's death—not after years of biomechanical research.

Choudhury et al. (2024) reinforce this pattern, showing that institutions often wait until public or legal pressure makes delay more damaging than action. These decisions reflect strategic risk management, not a lack of information.

Fan and Media Backlash

Public reaction further complicates reform. Fans and media often resist changes that alter a sport's aesthetics. Hamsund and Scelles (2021) found that even fairness-oriented technologies like VAR faced backlash. The Guardian Cap, designed to reduce impact in football, was mocked as making players look soft (The Sun, 2023). Similar ridicule met the Halo in F1 and early baseball helmets, delaying adoption and acceptance (Jenkins et al., 2015).

These responses reveal that optics, not effectiveness, often judge safety. When equipment alters the "look" of the game, backlash can shape institutional hesitancy and reinforce athlete resistance.

Legal and Financial Pressure as Tipping Points

In almost every case, external pressure—not internal initiative—forced change. The NFL's $765 million concussion settlement reshaped league policy more than a decade ago (Belson, 2013). The IOC modified the luge track at Whistler only after Nodar Kumaritashvili's death despite prior warnings (Wojtys, 2010).

Litigation has thus become a key driver of safety reform. Coughlin et al. (2009) calls this "post-incident governance," where institutions act to contain fallout, not prevent harm. These patterns expose the fragility of systems dependent on tragedy to justify change.

Synthesis: Toward a Reactionary Model of Safety Governance

A clear model emerges: Safety technologies are often available and validated long before they are mandated. Adoption is delayed by athlete resistance, institutional self-protection, aesthetic backlash, and the absence of legal consequences. Evidence matters—but only when paired with external pressure.

This review frames the question at the heart of this research: What factors delay the mandation of protective sports gear, and what finally overcomes this delay? The following case studies explore that question through the lens of timing, resistance, and institutional response.

Theoretical Framework: The Reactionary Model of Safety Governance

This study uses the reactionary model of safety governance to examine how and when sports institutions adopt safety technologies. First introduced by Coughlin et al. (2009) and expanded by Finch (2006), this framework suggests that safety reforms in high-risk environments often occur not when risk is identified—but after visible failure makes delay untenable. Change is not proactive; it is reactive. Regulation follows harm, litigation, or scandal rather than emerging from precautionary planning.

This model contrasts with idealized models of proactive governance, where risk assessments prompt early intervention. In practice, however, many organizations—especially those in the public eye—postpone action until their legitimacy or credibility is threatened. Reforms are shaped less by innovation than by institutional pressures that accumulate after an incident. As Finch (2006) notes, the "implementation gap" between research and policy often reflects hesitation, conflicting interests, and reputational fears—not a lack of solutions.

The reactionary model is especially relevant in sports, where tradition, visibility, and emotion heavily influence decision-making. Unlike in aviation or medicine, where safety is institutionalized, sports often struggle to balance entertainment and protection. As a result, safety gear may remain optional for years until a fatal incident—or public fallout—forces its adoption.

That said, the model has limitations. Not all reforms occur post-tragedy. Some leagues have taken semi-proactive steps, like the NFL's Guardian Cap trials or Formula 1's early Halo testing. These suggest that incremental shifts toward anticipatory governance are possible. For this reason, this study does not assume that all reforms are reactive. Instead, it asks to what extent the reactionary model explains sports safety governance—and whether outliers suggest a more considerable change.

Using this framework, the paper compares six cases to identify resistance patterns, tipping points for reform, and institutional behavior. The goal is to assess whether sports safety adoption consistently reflects reactionary governance and, if not, what the exceptions reveal about possible paths forward.

Methods

This study uses a qualitative, comparative case study approach to assess whether sports safety technologies are implemented according to the reactionary model of governance. Rather than aiming for causality, the analysis identifies patterns across multiple sports and evaluates how sociotechnical factors influence when scientifically supported safety innovations are mandated.

Six cases were selected: the HANS device in auto racing, the Halo in Formula 1, Guardian Caps in football, neck guards in professional ice hockey, batting helmets in Major League Baseball, and track safety revisions during the 2010 Olympic luge event. Each case met three criteria: a validated safety technology existed before a high-profile incident; adoption was delayed until after that incident; and the event and institutional response were well documented through credible sources.

Data came from primary and secondary materials, including league rulebooks, athlete interviews, policy documents, journal articles, and reputable news coverage. This allowed for technical validation of the technology and contextual analysis of how institutions, athletes, and the public responded.

Each case was analyzed using comparative thematic analysis. This process involved identifying recurring forms of resistance—such as athlete discomfort, aesthetic objections, or institutional liability concerns—and tracing the timeline from availability to implementation.

Particular attention was paid to the catalyst for reform, whether it was a death, lawsuit, or public backlash.

These elements were compared across cases to assess how closely each aligned with the reactionary model. While this is a qualitative and interpretive analysis, it seeks a structured and replicable understanding of how reform unfolds in different sporting contexts. This method allows the study to evaluate the extent to which reactionary governance explains delayed adoption—and whether any cases indicate movement toward more proactive systems.

Results: Patterns of Delayed Safety Implementation in Sports

Across all six case studies, a consistent pattern emerged: safety technologies that were validated and available were not widely implemented until after a high-profile injury or fatality. These delays were driven by athlete resistance, institutional inertia, aesthetic backlash, and legal or financial pressure. The following thematic breakdown shows how these forces interact across sports.

Athlete Resistance and the Culture of Toughness

Athletes often delay adoption due to concerns over comfort, performance, or tradition—even when the risks are well known.

HANS Device (NASCAR)

Developed in the 1980s, the HANS device aimed to prevent fatal head and neck injuries in crashes (Hubbard & Downing, 1989). Despite clear biomechanical evidence, drivers resisted wearing it, citing discomfort, restricted movement, and fears it could hinder emergency escapes (Gibson et al., 2013). NASCAR allowed voluntary use until Dale Earnhardt's fatal crash in 2001

forced a mandate amid intense media and public pressure (Bradley, 2021). The combination of cultural resistance and institutional caution was only broken when reputational risk outweighed resistance.

Neck Guards (Hockey)

Neck protection in hockey faced similar resistance. Despite decades of incidents—including Clint Malarchuk's 1989 near-fatal injury and Adam Johnson's fatal injury in 2023—players largely declined to wear protective neckwear due to discomfort and perceived interference with play (Faguy, 2023). Leagues avoided mandating it until Johnson's widely publicized death reignited calls for reform. Longstanding reluctance was overcome only when public outrage and renewed legal scrutiny made further delay untenable.

Batting Helmets (MLB)

Batting helmets were resisted for decades despite Chapman's fatal head injury in 1920. Players cited discomfort and visual obstruction, and many continued batting without helmets voluntarily. It wasn't until the 1970s that MLB mandated helmets—reflecting not sudden cultural change, but gradual legal and reputational pressures accumulating over decades (Jenkins et al., 2015).

Institutional Hesitation and Fear of Backlash

Even when data supported change, governing bodies delayed mandates, often out of fear of legal or reputational consequences.

Halo Device (Formula 1)

The Halo, a titanium cockpit frame designed to deflect debris and protect drivers' heads, passed extensive safety tests. Still, its adoption faced internal resistance from the FIA, teams, and drivers worried about aesthetics and visibility (Srinivasan & Demirel, 2022). Despite successful testing, the device was only mandated after a divisive vote in 2017—and its importance was not widely accepted until Romain Grosjean's 2020 crash, in which the Halo likely saved his life (Hughes, 2021).

Guardian Caps (NFL)

Guardian Caps were validated but faced resistance over aesthetics, cost, and tradition. Players and fans mocked their appearance, while teams hesitated to adopt them broadly. The NFL only mandated them for certain practices after internal data showed a >50% reduction in concussions (NFL, 2022; Cecchi et al., 2023), signaling a shift driven by accumulating evidence and risk management, rather than voluntary enthusiasm.

Luge Track Modifications (Olympics)

The Whistler Sliding Centre was flagged for excessive speed during test runs leading to the 2010 Olympics. Despite crashes in training and athlete concerns, officials made no significant changes. Only after Georgian luger Nodar Kumaritashvili died during a run was the start position lowered and safety barriers installed (Wojtys, 2010).

Public and Media Resistance to Visible Change

Public and media reactions to safety reforms frequently shaped institutional decisions—particularly when equipment altered the sport's appearance.

Halo Device (Formula 1)

Upon release, the Halo was lambasted online and in media as “ugly” and “ruining the look of F1.” Despite its safety function, initial public sentiment was overwhelmingly negative—only shifting after its role in saving lives became undeniable (Bishop et al., 2018).

Guardian Caps (NFL)

Guardian Caps were widely mocked on social media as “mushroom helmets.” Fans and even some players called them unnecessary or soft. The caps’ unconventional appearance dominated the narrative, sidelining early data about their effectiveness (The Sun, 2023; Guardian Sports, 2023). Only after multiple preseason trials showed dramatic reductions in concussion rates did sentiment begin to change.

These reactions often framed safety as a weakness and made visible reforms harder to implement, especially in image-driven sports.

Legal and Financial Pressure as Final Catalysts

Reforms often occurred only after institutions faced lawsuits or public scrutiny that reframed delay as a liability.

NFL Concussion Lawsuit

The NFL’s denial of concussion research was reversed after a 2011 class-action lawsuit by former players led to a $765 million settlement (Belson, 2013). This legal and financial reckoning led to sweeping changes in concussion protocols and equipment innovation.

NASCAR Post-Earnhardt

While the HANS device had been available for years, it was not until Dale Earnhardt’s death and the resulting public and legal scrutiny that NASCAR mandated head and neck

restraints (Kaul et al., 2016). The backlash exposed a reluctance to act preemptively—and demonstrated the reputational cost of preventable death.

Olympic Luge Response

The death of Kumaritashvili during a televised Olympic event forced officials to make immediate track modifications. Pre-game concerns had been documented but ignored. The public nature of the crash—and its proximity to the opening ceremony—left organizers with no choice but to respond visibly and quickly (Wojtys, 2010).

These cases demonstrate how institutional behavior changes not from recognizing risk but from fear of consequences.

Summary: A Consistent, If Troubling, Pattern

When viewed together, these six case studies reinforce the central premise of the reactionary model: scientific evidence alone is not enough to prompt reform. Instead, safety technologies become mandatory only after institutions are forced to confront the consequences of delay—through death, legal threat, or public outrage.

While some reforms, like the Guardian Cap trials or the early testing of the Halo, suggest emerging cracks in the reactionary cycle, these remain the exception rather than the rule. Even semi-proactive actions typically follow years of resistance and are often limited in scope. Sports safety governance still operates on a delayed feedback loop: harm first, reform second.

Discussion & Analysis

The six case studies provide strong evidence for the reactionary model of safety governance. In each instance, scientifically validated safety technologies were only mandated

after a high-profile crisis—a death, lawsuit, or wave of backlash—forced institutions to act. Despite differences in sport, technology, and timeline, the same pattern repeated: reform followed tragedy, not data.

Athlete Resistance as a Cultural Barrier

Athlete resistance proved consistent across sports, rooted in performance, discomfort, or tradition concerns. The HANS device, Guardian Caps, and neck guards all faced pushback despite evidence of their effectiveness. This resistance was particularly pronounced in sports that glorify toughness and risk. Athletes' reluctance to adopt new gear delayed reform—but institutional tolerance of that resistance was equally responsible.

Institutional Inertia and Calculated Delay

Governing bodies often hesitated to act—not due to ignorance but calculated risk avoidance. As Finch (2006) and Coughlin et al. (2009) note, institutions balance the cost of reform against potential backlash. Many delayed mandates until public or legal pressure made inaction untenable. The Halo and Guardian Cap cases show that even well-tested technologies can sit idle until external threats force adoption.

Media and Fan Culture as Reinforcing Forces

Fans and media frequently reinforced this hesitation. Equipment that altered a sport's appearance was often met with mockery, especially on social media. The Halo and Guardian Cap were both dismissed as unattractive or soft. This cultural resistance influenced athletes and institutional leaders who were wary of alienating audiences or damaging a brand.

Legal Liability as the Ultimate Motivator

In every case, the true catalyst for reform was a legal, financial, or reputational risk. The NFL concussion lawsuit, Earnhardt's death, and Kumaritashvili's crash all reframed delayed action as negligence. These events illustrate that safety changes often occur not because an organization wants to lead—but because it can no longer afford not to.

Exceptions and the Edges of the Model

While the overall pattern holds, there are signs of incremental progress. The NFL's Guardian Cap trials and Formula 1's early Halo testing represent moves—however slow—toward anticipatory action. These changes followed sustained pressure and data collection, suggesting that institutional behavior can shift with internal advocacy and successful pilot programs. Still, even these "proactive" reforms were preceded by years of resistance and external pressure.

Toward a New Model of Safety Governance

Breaking the reactionary cycle will require structural and cultural change across multiple levels of the sports ecosystem. First, governing bodies must be incentivized to act on evidence, not just in the aftermath. This could mean establishing formal risk thresholds that trigger automatic policy review or embedding independent safety committees into rule-making bodies.

Second, pilot programs should be institutionalized. As shown with Guardian Caps, limited trials can offer valuable data and shift the narrative toward prevention. These trials also help gather feedback from athletes—turning them from opponents of change into co-designers of better, more comfortable protective gear.

Finally, cultural narratives around safety and toughness need to be challenged. This starts with athlete education but must extend to fans and media. Reframing protective gear to enable

performance rather than undermining it is essential. Testimonials from respected athletes who credit equipment with saving their lives—like Grosjean or former NFL players—can be powerful tools for cultural change.

Until these shifts occur, sports safety reform is likely to remain reactive. The cases examined in this study reflect isolated incidents and a governance structure that relies on loss to justify change. Moving beyond this cycle means designing systems that treat risk mitigation as a priority—not a public relations response.

Conclusion

This study aimed to answer a critical question: What factors delay the mandation of protective sports gear, and what finally overcomes this delay? Across six diverse case studies—spanning motorsports, football, hockey, baseball, and Olympic luge—a consistent pattern emerged: despite strong scientific evidence and available protective technologies, reform was delayed until tragedy, litigation, or reputational crisis forced institutional action.

The delays were driven by a combination of factors: athlete resistance rooted in concerns over comfort, performance, and tradition; institutional inertia shaped by legal fears, financial risk, and reputational concerns; and public and media backlash that framed visible safety equipment as weakness or aesthetic disruption. These forces collectively created a sociotechnical environment where protective gear remained optional or resisted, even when its effectiveness was scientifically validated.

However, while these factors delayed action, a different set of forces ultimately overcame the delay. In every case, reform followed a tipping point—a fatal injury, a high-profile lawsuit, or public outrage so strong that continued inaction threatened the institution's legitimacy. Legal liability and reputational damage became the catalysts that transformed safety from an optional

consideration into a mandated requirement. Reform occurred not because institutions prioritized proactive protection, but because the cost of delay—whether legal, financial, or cultural—became too great to ignore.

Importantly, the case studies also revealed subtle signs of change. The NFL's Guardian Cap trials and Formula 1's early Halo testing suggest that under certain conditions, internal advocacy, pilot programs, and sustained data collection can shift organizations toward earlier action. These examples, while still rare, indicate that the reactionary cycle is not absolute: institutions can move toward anticipatory governance if incentives, narratives, and institutional structures are intentionally aligned to reward prevention rather than reactive damage control.

Yet overall, the findings confirm that in most sports contexts, protective gear is mandated only when delay becomes a liability. Reform is reactive, not proactive—driven by external pressure rather than internal commitment to safety. Breaking this cycle will require systemic changes at multiple levels: embedding independent safety oversight, institutionalizing pilot testing, elevating athlete voices in equipment design, and challenging cultural narratives that conflate toughness with risk exposure.

Until such changes occur, sports safety policy will likely continue to operate on a delayed feedback loop—where tragedy, rather than foresight, remains the primary engine of reform. The implications extend beyond sports, raising broader questions about how institutions balance innovation, safety, and risk governance in other high-profile, high-risk industries. In the end, preventing avoidable harm demands not only better technology, but a cultural and institutional willingness to mandate protection before loss makes reform inevitable.

References

Adams, W. M., Casa, D. J., & Drezner, J. A. (2016). Sport safety policy changes: Saving lives and protecting athletes. *Journal of Athletic Training, 51*(4), 358–360. https://doi.org/10.4085/1062-6050-51.4.14

Associated Press. (2024, September 20). Hotter summers are making high school football a fatal game for some players. *AP News.* https://apnews.com/article/2455ba5852d83f548754e44240abf99b

Belson, K. (2013, August 29). N.F.L. agrees to settle concussion suit for $765 million. *The New York Times.* https://www.nytimes.com/2013/08/30/sports/football/judge-announces-settlement-in-nfl-concussion-suit.html

Bishop, C., Arnold, J., & May, B. (2018). Effect of halo-type frontal cockpit protection on overtaking. *BMJ Case Reports, 2018*, bcr-2018-225597. https://doi.org/10.1136/bcr-2018-225597

Bradley, C. (2021, February 18). NASCAR: How did Dale Earnhardt die? The Intimidator's legacy. *Motorsport.com.* https://www.motorsport.com/nascar-cup/news/dale-earnhardt-death-how-died/5419883/

Cecchi, N. J., Callan, A. A., Watson, L. P., Liu, Y., Zhan, X., Vegesna, R. V., ... & Camarillo, D. B. (2023). Padded helmet shell covers in American football: A comprehensive laboratory evaluation with preliminary on-field findings. *Annals of Biomedical Engineering, 52*(10), 2703–2716. https://doi.org/10.1007/s10439-023-03169-2

Choudhury, R. D., Assumi, K. H., Nath, D., Kalai, S., & Nath, S. C. (2024). Progress of protective gear in preventing sports injuries. *Brazilian Journal of Development, 10*(3), e67830. https://doi.org/10.34117/bjdv10n3-012

Coughlin, M. J., Kelly, E. W., & Marcos, R. G. (2009). The role of litigation in influencing sports safety regulations: The case of motor racing. *Sports Health, 1*(2), 107–112. https://doi.org/10.1177/1941738109333946

Crockard, H. A., & Heilman, C. B. (2016). A revolution in preventing fatal craniovertebral junction injuries: The role of the HANS device. *Journal of Neurosurgery: Spine, 25*(1), 123–127. https://doi.org/10.3171/2016.1.SPINE151170

Ebben, W. P., & Suchomel, T. J. (2012). Physical demands, injuries, and conditioning practices of stock car drivers. *Journal of Strength and Conditioning Research, 26*(5), 1188–1198. https://doi.org/10.1519/JSC.0b013e31822d5306

Faguy, A. (2023, November 14). Arrest made in connection with death of American hockey player. *Forbes*. https://www.forbes.com/sites/alexfaguy/2023/11/14/arrest-made-in-connection-with-death-of-american-hockey-player/

Finch, C. F. (2006). A new framework for research leading to sports injury prevention. *Journal of Science and Medicine in Sport, 9*(1–2), 3–9. https://doi.org/10.1016/j.jsams.2006.02.009

Gibson, T. J., McElhaney, J. H., & Hubbard, R. P. (2013). Analysis of head and neck injuries in motorsports: The role of head restraints. *The American Journal of Sports Medicine, 41*(5), 1182–1190. https://doi.org/10.1177/0363546512473710

Guardian Sports. (2023). Frequently asked questions: Guardian Caps and football safety. *Guardian Sports*. https://guardiansports.com/faqs/

Hamsund, T., & Scelles, N. (2021). Fans' perceptions toward Video Assistant Referee (VAR) in the English Premier League. *Journal of Risk and Financial Management, 14*(12), 573. https://doi.org/10.3390/jrfm14120573

Hubbard, R. P., & Downing, J. R. (1989). Development and evaluation of the Head and Neck Support (HANS) device. *SAE Technical Paper Series.* https://doi.org/10.4271/892436

Hughes, M. (2021, September 14). Tech Tuesday: A close look at the Halo – and how it 'saved' Hamilton's neck in Monza. *Formula 1*. https://www.formula1.com/en/latest/article/tech-tuesday-a-close-look-at-the-halo-and-how-it-saved-hamiltons-neck-in.68Ajvw12Xza2P3JvuXGRO3.html

Jenkins, P. D., Lafferty, P. M., & Solomito, M. J. (2015). The evolution of head protection in baseball: A review of batting helmet safety and impact performance. *Neurosurgical Focus, 39*(1), E9. https://doi.org/10.3171/2015.4.FOCUS1591

Kaul, A., Abbas, A., Smith, G., & Steinmetz, M. (2016). Lessons learned from the Head and Neck Support device in professional auto racing. *Journal of Neurosurgery: Spine, 25*(6), 756–762. https://doi.org/10.3171/2016.4.SPINE151317

Kerr, Z. Y., Register-Mihalik, J. K., Pryor, R. R., Hosokawa, Y., Scarneo-Miller, S. E., & Casa, D. J. (2021). Barriers and facilitators faced by athletic trainers implementing NATA-IATF preseason heat-acclimatization guidelines in U.S. high school football. *Journal of Athletic Training, 56*(8), 816–828. https://doi.org/10.4085/1062-6050-0715.20

Ludvigsen, J. A. (2023). Football fans' contestations over security: Between offline and online fan spaces and channels. *Sport in Society, 26*(10), 1685–1700. https://doi.org/10.1080/17430437.2023.2183848

Malarchuk, C. (2014, October 7). Bleeding out. *The Players' Tribune.* https://www.theplayerstribune.com/articles/clint-malarchuk-bleeding-out

National Football League (NFL). (2022). Guardian Cap results: 'Exceeded our expectations'. *NFL Player Health & Safety.* https://www.nfl.com/playerhealthandsafety/equipment-and-innovation/engineering-technology/guardian-cap-results-exceeded-our-expectations

Srinivasan, S., & Demirel, H. O. (2022). Quantifying vision obstruction of Formula One (F1) Halo concept variants using digital human modeling. *Proceedings of the 7th International Digital Human Modeling Symposium.* https://pubs.lib.uiowa.edu/dhm/article/31755/

Stark, N. E.-P., Begonia, M. T., Jung, C., & Rowson, S. (2024). How shell add-on products influence varsity football helmet performance. *Annals of Biomedical Engineering, 52*, 2923–2931. https://doi.org/10.1007/s10439-024-03627-5

The Sun. (2023, August 10). NFL Guardian Caps face ridicule despite success in reducing concussions. *The Sun.*

https://www.the-sun.com/sport/12184479/nfl-guardian-caps-preseason-concussions-colts-jonathan-taylor

Tjønndal, A., & Wågan, F. A. (2021). Athletes' and coaches' attitudes toward protective headgear as concussion and head injury prevention: A scoping review. *Frontiers in Sports and Active Living, 3*, 680773. https://doi.org/10.3389/fspor.2021.680773

Wojtys, E. M. (2010). Sports injury prevention failure. *Sports Health, 2*(3), 185. https://doi.org/10.1177/1941738110369218