FOCUS PIECE

Innovations in Auto Racing Safety to Reduce Head/Neck Injuries

A public health perspective

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Formula 1 Racing (F1)
cc Jose Vivanco

The most common cause of fatal injury and long term disability in auto-racing are repeated head injuries [1]. In 2010, the Centers for Disease Control and Prevention estimated that traumatic brain injuries (TBIs) accounted for approximately 2.5 million emergency department visits in the United States either as an isolated injury or in combination with other injuries. Among those individuals who presented for care, approximately 2% died [2]. TBI is most often caused by motor vehicle crashes, sports injuries, or simple falls. Types of head and neck injuries include concussion, skull fracture (basilar skull fracture without penetration of helmet by foreign body), vascular shearing, diffuse axonal injury, other TBI, and spinal injuries. The likelihood of injuries such as TBI is significantly increased in competitive motor vehicle racing, such as in Formula 1(F1), and consequently significant resources have been committed to design improvements that reduce the incidence and severity of injury during competitive racing. Understanding design innovations in competitive racing is invaluable as they form the catalyst, framework, and experimental sandbox for mass market auto safety innovations.

A Brief History of Auto-Racing Safety

Since the inaugural auto race of the 1950s, head and neck trauma remains the single greatest injury risk to drivers due to gravitational force loading in open wheel/open cockpit racing [7]. Fortunately, significant decreases in the overall rate of injury have occurred over the past 25 years. In the early days of F1 during the 1960's, one in eight crashes resulted in a fatality [7]. According to F1 record, safety at the time was merely in the form of a warning sign: "risk of serious or fatal injury". Over time, crash investigation lead to an increase in awareness and focus in research to prevent future fatal injury.

As early as the 1940s, researchers at Wayne State University began studying an animal model to relate external load with brain injury to gain insight into the mechanism for which the brain becomes injured in sports and/or motor vehicle crashes [3,4]. Research resulted in an array of safety measures in the form of car design modification, environmental or circuit changes, and driver technology. Perhaps most importantly, crash investigation and research lead to significant regulatory changes in organizational policy with implications for the field of public health.

Driver deaths in crashes - F1 alone:

1950-1960: 30
1961-1970: 24
1971-1980: 13
1981-1990: 7
1991-2000: 4
2001-present: 1

Policy interventions for driver safety began in 1963 with the mandate of the helmet in all F1 sanctioned races. The helmet was originally made of animal skin and open-faced, but later developed into a hard outer shell meant to ward off external forces combined with a soft inner padding to cushion blows. Unfortunately, since policy intervention, drivers have complained of helmet weight, restricted motion, slower speed due to absence of aerodynamic design, neck fatigue, poor visibility, poor ventilation and difficulty with removal, particularly if unconscious. Due to many of these problems, some race drivers refused to wear the protective gear until a mandate was passed. Over time the design of the helmet evolved based on evidence from both real raceway tragedies and laboratory studies on cadaver/manikin models [8].

The use of manikin models as a substitute for human models has also stirred debate recently. The Snell Memorial Foundation (SMF). a non-profit organization that provides the majority of data for F1 helmet gold standards publishes a report every five years known as the "Protective Headgear for Use with Motorcycles and Other Motor Vehicles" [9]. This report defines the new standard for which F1, among other divisions, uses to make helmet regulations. Yet, the report is based on testing performed on manikin heads and "helmet testing does not seek to precisely reproduce real life situations…it does not include responses of the neck or body as they react with the head to impact" [9]. Thus given that the SMF is the most advanced source of helmet data in the world, there is clearly an urgent need to redefine the testing technology standard to realistically simulate the brain's response high-speed impact or rotational motion.

In 2004, Olvey and colleagues conducted a pilot study to investigate the use of a new technology to study TBI. The researchers used micro-accelerometers in the ear-buds of all drivers across multiple leagues in a single race season [10]. The study showed that the device could capture precise and reliable data without being dislodged in any of the 1500 crashes observed [10]. Unfortunately, this study has not been transformed into a suitable model for testing the impact of rotational forces on the live human brain, thus the true human tolerance to brain injury has yet to be established [11].

Looking Forward

A crucial question for health care and design enthusiasts, is how can we more effectively leverage the rich environment of competitive auto racing to learn and improve the automobile driving experience.

Development since the 1960s

Types of Injuries

- Concussion
- Whiplash/neck sprain
- Skull Fracture
- Basilar Skull Fracture
- Vascular Shearing
- Diffuse Axonal Injury
- Other TBI
- Cervical spine

Formula 1; cc Christian Sinclaire

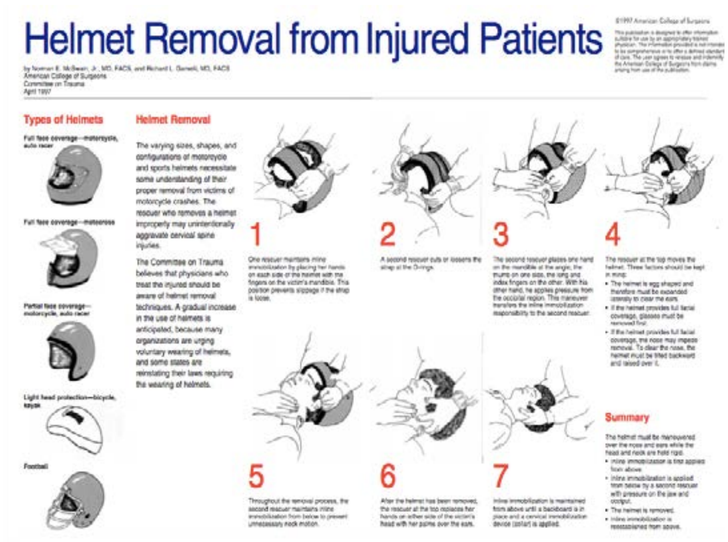
INJURY PREVENTION

1950:	**No regulations**—*dress code directed toward "elegance"; no medical backup*
1960:	**first ever safety measure introduced** *(disk brakes—shortened braking distance as on every street car now)*
1961:	**roll-bar**
1963:	**Helmets** *(open/leather-invented 1954/Flags/ Fireproof suit/FIA)*
1970:	**circuit inspection/safety**
1977:	**standard helmet**
1978:	**drivers must have super license**
1984:	**fuel tank between driver & engine**
1985:	**initial crash tests for frontal impact**
1990:	**detachable steering wheel**
1992:	**official safety car**
1999:	**wheels must be tethered to chassis** *(NASCAR still does not enforce)*
2000:	**carbon fiber wall of cockpit expanded**
2004:	**new helmet standard**
2009:	**Video analysis improved—incident report with video evidence must be published**

First, as recommended by Orvey and colleagues, all F1 drivers should be required to use the micro-accelerometer attachment in live racing and during practice laps to gather precise data on the forces placed on the brain during high speed collisions. If effected the F1 division alone would provide sample size of sixty drivers per year. The sample is ideal, as the drivers are already willing participants in an extremely high-risk activity and are already aware that high-speed crashes may be fatal or cause TBI. Data from the micro-accelerometers can be combined with live footage from both car video surveillance and from brain imaging scans performed post-collision to further reduce the numbers of head/neck injuries through awareness and prevention strategies. Further, it can be applied globally to sports related head injuries. Understanding of biomechanics of TBI as a result of high-speed crashes will allow us to evaluate this mechanism of injury to the fullest extent of our technological resources. This information should be published for open educational access, be used to create a novel helmet design for the next Snell revision and for widespread application to other at risk populations. An additional, quick and far less labor-intensive intervention, involves policy change to include existing prevention strategies with known advantages.

Second, there should be enforced policy requirements in place requiring the use of Eject Helmet Removal Systems (EHRS). The 2015 Snell report on helmet removability states that a helmet must be able to be removed by a single technician from an unconscious victim using simple common hand tools in no more than 30 seconds [9]. Any form of monitoring is not mentioned and Eject helmet removal systems are not included. Since the 1980s, it was accepted as common knowledge that removing an already tight-fitting helmet from an unconscious victim with injury related edema is a dangerous practice capable of worsening existing injuries or creating new, potentially fatal impairments. Despite limited data, the EHRS has been hailed as the preferred method for helmet removal in motorsports by the multiple societies such as the International Racing League, the American Speed Association, and the American Medical Association [12].

Although unbiased data should be collected from independent studies, enough evidence is present to demonstrate potential clinical benefit of the device. Even though it was made compulsory as early as 2010 in some race leagues, such requirements are not in the standard by-laws for racing helmet design [8,9].



Altering language in the SMF policy to include EHRS in the design of all helmets will encourage leagues to enforce the rules and drivers refusing to comply will not be allowed to race.

In Conclusion

What was once known as a sport where drivers had a fate as certain as death has now experienced only a one loss in the past 15 years as a direct result of safety measures. The collaboration between public health officials, physicians, research scientists, and innovators with a deep understanding of injury mechanism and preventive strategies has helped to build not only a safer sport, but also a safer environment for everyone. Micro-accelerometers and the EHRS have added to the extensive list of technological advancements, environmental/circuit changes, car design modifications, driver regulations and policy standard regulations that have altered the identity of the sport of auto-racing. Understanding the advancements in auto racing is no longer just for the professional racer, design enthusiast, or sports fan. A closer study of advancements, methods, and trends in professional auto racing can provide insight into new strategies to improve automobile safety beyond the race track and thereby improve mass transport safety.

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