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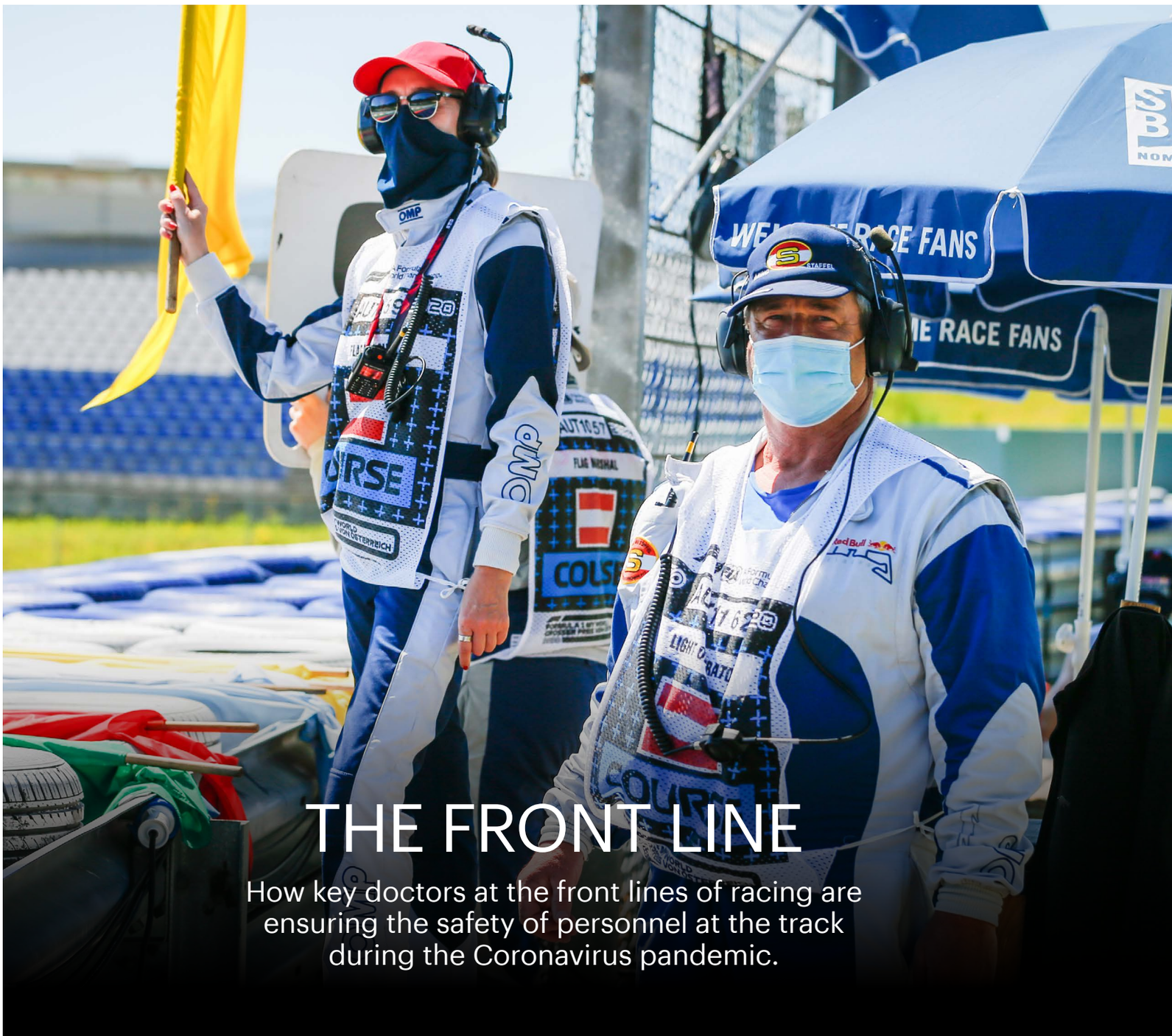

THE FRONT LINE

How key doctors at the front lines of racing are ensuring the safety of personnel at the track during the Coronavirus pandemic.

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INTRODUCTION/

Since our last edition the world has changed significantly and motor sport has taken a back seat while everyone, including the FIA and all the medical fraternity, have focussed on the pandemic. But as racing returns, our cover story looks at how the FIA has introduced testing and special arrangements to ensure those involved in Formula One and other championships can remain as safe as possible from COVID-19. We also look at some of you who are normally involved in providing medical care at motor sport events, what you have been doing, how it's affected you and how you are getting motor sport back up and running.

The FIA has worked in partnership with the International Federation of Red Cross and Red Crescent Societies, donating via an auction of motorsport memorabilia over $2million as well as supplying National Sporting Authorities with vital personal protective equipment (PPE). The way we all work has changed, with PPE and electronic briefings and online meetings being the new "normal". Indeed, many planned medical meetings have been converted to online and this is likely to be the way forward for most conferences for the rest of 2020.

Zolder, a circuit loved by many, near to the beach in Holland with a direct rail link to Amsterdam is the focus of our view from the grass roots interview with the Chief Medical Officer and Chief Nurse who explain how they work and train.

There is also a look inside the medical facilities at Zandvoort, and an interview with Pirelli F1 chief Mario Isola who unbeknown to many volunteers as a part-time ambulance driver in Italy.

Stay safe.

The Editorial Board

GLOBAL NEWS

FIA INVESTIGATING WIDE-RANGING SAFETY IMPROVEMENTS

The FIA is investigating a number of safety-improvement across circuit racing, including the use of 'deceleration' solutions in run-off areas, a review of front wing designs, improved debris containment and early warning systems.

As with all FIA safety projects, this work incorporates the findings of accident investigations, this time including the 28 serious and fatal accidents that occurred in 2019.

"Our findings related to circuit racing form the basis of a range of technical and operational initiatives, both to prevent serious accidents occurring and to mitigate the consequences if they do," said FIA Safety Director, Adam Baker.

The FIA Serious Accident Study Group, led by President Jean Todt, approved a number of solutions including measures that will prevent or mitigate debris from being ejected from single-seater cars during an accident.

Technical solutions will be developed which aim to ensure large debris is contained and/or restrained with the crashing vehicle. This includes the development of tethering systems – similar to wheel tethers on many single seater cars – for larger components of body work and less intrusive and more novel design solutions for small parts.

This work will also consider whether future generations of single-seater cars could incorporate front wing designs that include 'controlled failure' points. For example, the front wing main plane could be frangible such tha, in the event that the outer sections of the wing receive an impact, only these sections would detach, in order to relieve the load on the assembly and specifically nose mounting.

In addition, efficient deceleration solutions for slowing out-of-control cars within run-off areas are being looked at, including the use of anti-skid paint and high-friction surfaces.

TOM WEISENBACH NAMED EXECUTIVE DIRECTOR FOR ICMS

Veteran motor sport executive Tom Weisenbach has been named executive director for the International Council of Motorsport Sciences.

Weisenbach has over 23 years of experience in motor sport including working with the NHRA, Indianapolis Motor Speedway, IndyCar and Keystone Marketing. In 2013, Weisenbach launched the Motorsports Safety Education Foundation where he worked with sanctioning bodies, race tracks, and drivers on safety education.

"I am extremely excited for my new position with the ICMS," said Weisenbach.

Dr Rob Seal, chairman of the ICMS said that the appointment of Weisenbach will enable the ICMS to stay at the forefront of innovation and initiatives in motor sport safety.

"The ICMS is looking forward to working with Tom as we build on our strengths," said Seal. "Not only to ensure that we remain vibrant and at the forefront of innovations and initiatives in motor sport safety, but that we continue to grow and disseminate our knowledge more widely."

In addition to Weisenbach's appointment the ICMS headquarters will move to Indianapolis, whilst the 2020 annual conference set to take place in December this year will now to be hosted virtually due to the Covid-19 pandemic.

"After much consideration, in view of the global uncertainty created by the COVID-19 pandemic, the Board of Directors of the ICMS has made the decision to host its 2020 Annual Congress virtually," said Seal. "It is hoped that this format for the 2020 meeting will permit the ICMS to reach a broader international audience and to include a wider variety of presenters."

LECLERC VOLUNTEERS WITH MONACO RED CROSS

While racing was put on hold at the height of the Coronavirus pandemic, Ferrari F1 driver Charles Leclerc found time to volunteer for the Monaco Red Cross.

Leclerc delivered meals to elderly people who had to shield in their homes, helped transport equipment to the Princess Grace Hospital Centre, and distributed meals to Red Cross volunteers.

He as joined by footballers Cristiano Ronaldo and Paolo Maldini in supporting the Red Cross, with Leclerc also assisting Princess Charlene of Monaco's #BehindTheMask initiative to raise money for the World Health Organization's Covid-19 response fund.

"In this moment of emergency even the tiniest action can lead to an enormous result," said Leclerc on his social media channels. "Let's join together and continue fighting this challenge with courage. Help me support those who never give up."

FIA APPOINTS NEW SENIOR RESEARCH ENGINEER

Corrado Casiraghi, former Technical Director of Tatuus Racing, has been appointed to the FIA Safety Department as a Senior Research Engineer.

After studying for his master's degree in aerospace engineering from Politecnico di Milano university, Casiraghi became aerodynamic designer for Tatuus Racing in 2000 before taking up the role as Technical Director in 2012.

The Italian chassis maker provides cars for a number of single-make championships including regional Formula 4, Formula Renault, and the W Series. These are all crucial stepping-stones for young drivers looking to climb the ladder in motor sport.

Casiraghi oversaw the development of numerous chassis used in these championships, including the Tatuus FT50 used in the Toyota Racing Series which featured innovations such as an electro-actuated gearbox.

He was also involved in the design of the USF-17 and the PM-18 which are all used in junior categories for IndyCar's USF-2000 and Indy Pro 2000 'Road to Indy' series.

COLOURED RAIN LIGHT SYSTEM TO BE TESTED

The FIA will test a coloured rain light system which will display flag conditions on-track, as part of its recommendations for increased driver safety.

The system will utilize existing rain lights which are mandatory on the rear end of all cars involved in circuit racing, to display the current track flag conditions and improve driver visibility of flags being shown by race control.

This means if there is a yellow flag in a sector of the track then the rain lights would turn yellow, with the FIA also proposing that the rain light could be used as extra warning for a driver approaching a yellow flag zone.

"Although further testing and research is required, this adaptation of the rain light usage could reduce driver notification time, improve the reliability of driver notification and better allow drivers to make an appropriate and proportionate reaction in the case of yellow flag deployment," said the FIA in a statement.

Proposals for this system come after 28 accidents related to circuit racing were approved by the FIA Serious Accident Study Group, which is led by FIA President Jean Todt.

NORRIS SUFFERS BACK PAIN FROM TIME OUT OF CAR

McLaren driver Lando Norris revealed he suffered from back pain on F1's return at Austria, which was triggered by his time out of an F1 car.

Norris suffered from pain and bruising in his back and chest over the course of the weekend.

He eventually had to take painkillers to get through the second race at Austria and in the days between the back-to-back events at the Red Bull Ring, Norris flew back to the UK to get a diagnosis from specialists.

"It's just bruising from being out of the F1 car for so long, and then getting back into it and straight back into a race weekend, doing so many laps and so on," said Norris. "It wasn't something I could really prepare for or know about until after we did the first weekend."

Norris said that he changed his seating and steering wheel positions after the first Austrian Grand Prix weekend, due to the change in his body shape that occurred while he was out of the car and the UK was on lockdown.

"Having put on so much muscle over the break, I was just a bit out," added Norris. "I was slightly shaped differently in my seat, so I had to change a few pads around and a bit of my position."

DOUBLE-HALO STRUCTURE DEVELOPED BY REVOLUTION CARS

Revolution Cars has developed a version of the Halo cockpit safety device for use on two-seater sports prototype cars, calling it the 'Double-Halo'.

The new double-halo design is designed to protect both the driver and the co-driver and was manufactured using an energy-efficient infusion process.

It utilizes FIA-approved ROPT510 roll cage which provides similar levels of safety as a closed cockpit of a Le Mans prototype.

It will be fitted to the company's A-One sports prototype car and replaces the forward longitudinal bars on the current FIA approved roll cages, weighing just an extra 2kg.

"We designed the A-One to give more elbow room than other prototype racing cars, making it easy to operate both solo and with a passenger aboard," said Phil Abbott, Revolution Cars managing director.

"By introducing the 'double-halo' we are giving drivers and their instructors or corporate guests the same level of safety they would expect in a world championship type race car," added Abbott.

The device was also tested with several top drivers including Sir Chris Hoy, who regularly races LMP2 cars at Le Mans.

"The double-halo gives a real sense of security and still has great visibility," said Hoy. "I didn't even notice it once up to speed."

FIA RAISES €2M FOR GLOBAL COVID-19 RESPONSE

The FIA teamed up with the International Federation of Red Cross and Red Crescent Societies (IFRC) to raise money for COVID-19 relief as part of their long-standing partnership.

The charity auction was held on 15-22 June with RM Sothebys, involving Formula One and other motor sport drivers under the banner #RaceAgainstCovid.

The auction consisted of 95 motor sport memorabilia items, including a McLaren MP4-24 Show Car which was sold for £66,000, Damon Hill's 1995 F1 racing suit and helmet which was auctioned for £39,600, and an Eau Rouge sculpture by Paul Oz which achieved a sale of £48,000.

Altogether the auction raised €944,392 which was added to the €1,000,000 already donated by the FIA Foundation, which will go towards fighting the COVID-19 pandemic.

"I am delighted to give a cheque for almost €2 million raised by the charity auction to benefit the IFRC's global COVID-19 response" said FIA President Jean Todt.

The FIA's partnership with the IFRC involves a number of joint initiatives to raise awareness on the importance of first aid knowledge through the FIA worldwide network of clubs.

As part of this, the IFRC has delivered first aid training to Cross Country competitors in Qatar, enabling them to provide immediate assistance in remote locations during events prior to the arrival of emergency services.

WRC RESTARTS IN SEPTEMBER UNDER REVISED CALENDAR

The World Rally Championship will restart in September under a revised calendar, after the first part of the 2020 season was affected by Coronavirus in March.

The revised calendar will start from September with Rally Estonia, a newcomer to the calendar, set to be one of five events that the FIA and WRC Promoter plan to run.

This means there will be altogether eight rounds in 2020 including the three that have already taken place in Monte-Carlo, Sweden and Mexico earlier in the year.

Each event will be working under the guidance outlined by the FIA COVID-19 Code of Conduct, with each promoter working hard to ensure there are mitigation plans around COVID-19 testing.

"WRC Promoter has worked tirelessly with the FIA, our competitors, teams and event organisers, in exceptional circumstances, to revise the calendar," said WRC Promoter's senior director events, Simon Larkin. "Our combined determination enables the WRC to restart at an appropriate time and we're confident of delivering a season worthy of world championship status."

FIRST BIOMETRIC FIRE-PROOF UNDERWEAR CREATED

The first fire-retardant undershirt equipped with biometric sensors has been homologated by the FIA, enabling real-time monitoring of a driver's state of health.

The undershirt developed by Marelli and OMP uses a Vital Signs Monitor (VISM) to monitor a driver's physical health including stress, fatigue, and alteration, through the use of an electrocardiogram and thoracic expansion.

OMP made the fire-resistant garments while Marelli developed the electronics, data acquisition and telemetry techniques.

The solution used by Marelli complies with the FIA guidelines on the usage of biometric data, which ensures a competitor's privacy.

"We believe this is a major step forward in the development of motorsport safety systems and active driver aids for passenger cars too," said Riccardo De Filippi, Senior Vice President and CEO of Marelli Motorsport.

AUTO+ MEDICAL VIEW FROM THE GROUND

VIEW FROM THE GROUND:

The latest column from the frontlines of grassroots motor sport focuses on the medical operations at Circuit Zolder. Chief Medical Officer Dr Erik Beuls and Chief Nurse Chris Dupont discuss the differences between paramedics and doctors in Belgium, and the rigorous training they give their medical team.

DR ERIK BEULS

CHIEF MEDICAL OFFICER, CIRCUIT ZOLDER

"I have always had a special interest in motorsport, so when I graduated as a medical doctor in 1994 I contacted the Chief Medical Officer at my local racetrack in Zolder and asked him if I could join the medical team. And 25 years later I'm still there, enjoying myself as much as during my first race weekend. In 2010 I was asked by our CMO if I would be interested in taking charge of the medical team and become the new Chief Medical Officer for Circuit Zolder. I put forward a couple of conditions such as having Chris as my Chief Nurse and assistant at the racetrack.

Most of the motorsport work that I have done has been at my "home" racetrack in Zolder, but I have also had the opportunity to do some motorsport medicine related things elsewhere. I have been part of the medical team at Spa Francorchamps for the F1 weekend, at Lydden Hill for the World Rallycross Championship, at the Nürburgring for the Historic Grand Prix, at Ypres for the ERC rally, for some local rallies. Together with our extrication team I have also been to Assen and Zandvoort in the Netherlands to help them train their extrication teams.

I have got about 15 medical doctors in my team at Zolder, most of them are regulars who have been on the team for a long time. Apart from the medical team at Circuit Zolder there are quite a few doctors involved in motorsport medicine elsewhere in Belgium, for example at Spa or at the local rallies. Regrettably, there is (for the moment) not a lot of cooperation between the different teams, something I would like to try and change in the future.

The Covid-19 pandemic has confronted us as medical professionals with some new and unforeseen problems we will need to tackle. Over the last couple of years, we have been making plans for a new medical center at Zolder and at the moment we are very close to getting approval so we can finally start building. A lot of effort goes into training and retraining our medical team, and I can confirm that there are little to no limits to Chris' creativity when it comes to inventing new training scenarios. Surprises will happen, fake blood will flow, and sometimes even pyrotechnics will be used!

In my opinion the nurse and the doctor in the team are complementary and synergistic: what they can do as a team is much more than the sum of what both of them can do as individuals. They both contribute their own specific skills, knowledge and experience to the team and each of them brings what the other one is lacking. Chris and I have been working together in motorsport medicine for more than a decade now and over time we have become so responsive to each other that there's often very little communication going on during a medical intervention: we both know what needs to be done, know who's going to do it and know what the other one is going to do.

I would like to see more cooperation between the different motorsport medical teams across Belgium. It's a tiny country but even both Zolder and Spa Francorchamps each have their own medical teams functioning completely independent from each other. There are big advantages to be found in working together and sharing knowledge, experience and skills.

The biggest thing I have learned working in motor sport is that when you look at the world of high-level motorsport from the outside it all looks very glamorous, professional and well organized. But when you're on the inside you realize that there's a huge amount of work involved, mostly going on behind the scenes and relying upon large numbers of volunteers passionate about motorsport. These people usually do not get the recognition and appreciation they deserve, and I'm not talking about just the medical teams. When I tell people that I'm a motorsport doctor they often think that I'm doing heroic stuff day in day out, when mostly it's sitting in a car by the side of the racetrack in the pouring rain or blazing sun for eight hours straight with nothing at all happening! But I still love my job and wouldn't trade it for anything."

Photo credits: Circuit Zolder Medical Team

AUTO+ MEDICAL VIEW FROM THE GROUND

CHRIS DUPONT

CHIEF NURSE, CIRCUIT ZOLDER MEDICAL TEAM

“I started working in motor sport in 2005, when I just graduated as a nurse, as member of a local medical team for rallies and member of the extrication team at Spa Francorchamps. That same year I joined the medical team from the racetrack at Circuit Zolder. In the following years my engagement at the Zolder racetrack and the work increased so much that I had the opportunity to work on a freelance basis as a nurse/paramedic in motor sports.

I have previously worked at the circuits of Zolder, Spa Francorchamps, Lydden Hill and the karting circuit at Genk. This for local races and karting, F1, F2, FIA GT1, FIA WTCC, FIA Truck racing, DTM, Euro NASCAR, local motorcycle races, IDM Superbike, and FIM Endurance. Besides the work at the racetrack I also did some local rallies, the FIA World rallycross, ERC Ypres rally and the East African Safari Classic rally through Kenya and Tanzania.

At this point I’m the chief nurse of our medical team at Zolder. It means that I’m responsible for the planning for the nurses and Emergency Medical Technician’s (EMT) for all the events we cover. I am also responsible for the coordination of interventions, contact with the local Emergency Medical Services (EMS), training our team, the medical equipment, disaster preparedness and management. As medical team we do not only cover the race events, but almost every event or training session for cars and motorcycles. Apart from that we also organize education and training sessions for our medical team on a regular basis. I have quite a vivid imagination when it comes to creating incident and accident training scenarios, which means every so often the team can get a call from race control during an event to respond to a crash, but it turns out to be one of my unexpected exercises! They like it, they learn from it, and they ask for more of the same. That’s the great spirit of our entire medical team, they are always eager to learn and get better.

In Belgium we officially don’t have paramedics, we have EMT’s or nurses. The nurses who work at the EMS ambulances need to do EMT training or have a special degree in emergency medicine and intensive care. This last group can be compared to paramedics. I’m certified as both a critical care and flight paramedic, so I know both sides of that field of work. The difference between our work as a nurse/paramedic from a doctor is that we are more practical, we have more overview of the scene, we are used to work outside a hospital with minimal equipment, we are good in improvising at the scene. On the other hand doctors have specific medical knowledge and skills that we nurses don’t have. That’s why a combination of a doctor and nurse/paramedic is the way to go in mine opinion. This is the reason why for many years we work with a team consisting of an experienced driver, doctor and nurse in our medical cars, the same way our prehospital advanced trauma & critical care teams work, apart from the driver, during daily EMS calls.

We don’t split it in training for doctors or nurses/paramedics, EMT’s or extrication team. Two times a year we organize an entire day of training about motor sport medicine, which is always a combination of some theoretical parts and practical training. For this we analyze the accidents and interventions from the last year using the internal CCTV footage from the start of the crash until the end of the medical intervention. First, we let them watch the crash and let them think how they think they would approach the incident, followed by the actual footage of the medical intervention. After this we discuss what went well and what we can do better. For the practical part of the training we exercise in the use of for example the vacuum matrass, rapid sequence intubation, failed airway management, traumatic arrest, the approach and briefing of a victim in our medical center and extrication training. We also use extensive and realistic scenario training, where we simulate a crash on the race track and the crew need to do the whole intervention on the scene, transport the victim(s) to the medical center and stabilize them in the resuscitation unit until transport to the emergency department of a local (trauma) hospital is possible.

“I WOULD LIKE TO SEE MORE RECOGNITION FOR MEDICAL TEAMS INVOVLED IN MOTOR SPORT”

I would like to see more recognition for the medical teams involved in motor sport. Not only in Belgium, but around the world. As with every event in motor sport, music festival etc. around the world the medical aid is seen as a need to have, but also as something that costs money. I would like to see more cooperation between all the medical motor sport teams, there is so much knowledge scattered between the teams of the different race tracks when sharing this knowledge could benefit every team. This is also a thing that is going on around the world.”

AUTO+MEDICAL FEATURES

FEATURES

THE FRONT LINE

As racing gets back underway, *AUTO+ Medical* speaks to the key doctors and personal at the front lines of motor sport who are ensuring the safety and wellbeing of everyone at the track during the Coronavirus pandemic.

Over 30,000 Covid-19 tests were administered over the first six Formula One Grand Prix weekends of 2020. Only a handful returned positive.

The most public of these was the positive test for Racing Point driver Sergio Perez but, as with the other cases, he was isolated and his recent contacts traced. And Formula One cointinued to run without a hitch.

The whole operation and the minimal positive results are testament to the preparation work that the medical community put in during the months leading up to the first race.

“It’s really incredible,” says FIA Medical Commission President, Professor Gérard Saillant. “If you have told me that would be the case three months ago, I would not have believed you. But everybody was very involved in this challenge, from the FIA, Formula One, the teams, the staff and our responsibility was very well understood by them.”

The most important aspect to this was not at the track but the checks that were in place before people even arrived at the event.

"Before the Grand Prix it was very important to prepare and to be sure that everyone was negative, everybody was in a good shape, they have not had any contact with a positive case and so on."

No doubt this was the major factor in there being so few positive tests on event itself, especially in the early part of the season where there were just two positive cases over three races.

This preparation was a key element in the 81-page Return to Motorsport guidelines that were issued by the FIA in May. Saillant and his team collaborated with FIA Member Clubs, governments, and the World Health Organization to come up with the guidelines and assess the feasibility of hosting races safely in what is considered to be a 'mass gathering' during a pandemic.

"It was three or four very difficult months because the situation is not so good with Coronavirus still circulating," says Saillant. "For the FIA it was quite a big challenge to do the restart for F1, and to be honest I was not so confident. But we changed the impossible to possible due to the fantastic job by the FIA Safety Team, technical department, and everyone who was involved."

With F1 being the first international sporting event to restart, Saillant says the sport has been a test bed for the WHO and International Olympic Committee (IOC) as they plan the safe return of the Olympic games in Tokyo which have been postponed until 2021.

"Before F1 there was only national football events in Germany, in Spain, and in UK," says Saillant. "The WHO and IOC are very interested in our work, especially with the Olympic project in Tokyo for next year."

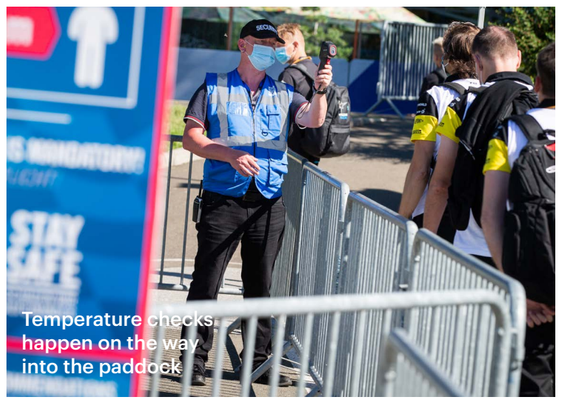
STRICT MEASURES

Normally F1 teams would take around 400 to 500 personnel to each race, but under the new guidelines this was reduced to the bare minimum of 80 people to limit the risk of spreading Coronavirus.

Regular testing must take place for all trackside personnel, officials, and media, ensuring social distancing is practiced, with personal protective equipment (PPE) masks being worn at all times in the paddock.

They must also stay within 'team bubbles' to limit the risk of an outbreak, which means personnel from Ferrari would not be able to mix with Mercedes personnel. In the case of Pirelli, the strict guidelines mean that when delivering the tyres to each team garage their representatives must wear full PPE to be compliant.

The FIA has to work closely with Public Health Officials in each country to determine the protocol for suspected or actual positive cases, while also ensuring that Covid-19 procedures do not become an additional responsibility of the normal medical staff or Chief Medical Officer at each race.



Temperature checks happen on the way into the paddock

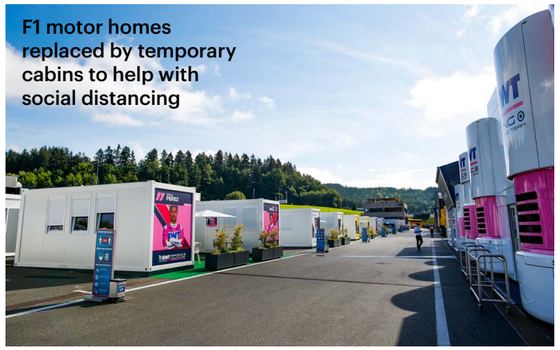
"We set up weekly meetings with Public Health Officers from Austria, Hungary, Silverstone, and Barcelona since the end of May," says Dr Pau Mota, FIA Head of Medical and Rescue. "The idea is not to engage with the normal medical staff of the event. It's close work with the testing company, Public Health Officers, and the Covid-19 staff from the FIA to ensure that any suspected case, uncertain case, or positive case is managed in a legal and transparent way."

At each race a public health representative was present to announce cases to the government and declare if there is an outbreak, or management of positive cases onsite. The challenge for the FIA is to adapt to the different ways of managing cases in each country, as they found between Austria and Hungary.

"Every day we did an average of 500 Covid-19 swab tests and in that you always have between five and 10 cases that are not clear and you have to manage," says Mota. "In Austria, the Public Health Officer and I agreed to manage that together. We then gave them data on the unclear cases, which they use to follow the official procedures. In Hungary it was the other way around, they just announced every single suspected case and we adapted our strategy to that."

For each test result the FIA will keep track and inform the Formula One Management accreditation department, in case there is a positive result and a pass needs to be deactivated to stop access to the paddock. In Hungary, where the first positive case showed up, there was a clear chain of command that kicked into action when isolating their positive case.

Ariane Frank Meulenbelt, Vice President of the Hungaroring, explains: "Locally the decisions


F1 motor homes replaced by temporary cabins to help with social distancing

> **"BEFORE F1 THERE WAS ONLY NATIONAL FOOTBALL EVENTS IN GERMANY, SPAIN AND THE UK"**

came from the pre-appointed hygiene officer. He was the one that was informed first, and they take all the further steps towards the local health authorities and discusses quarantine or contact tracing. Then it's taken over by the local authorities and they run essentially their normal procedure as per the country."

In Hungary the circuit promoter teamed up with Budapest-based clinic Semmelweis, to pre-test each of their staff members and medical team. But within the F1 paddock it is Eurofins, one of the top global scientific testing companies, that provide each of the Covid-19 swab tests throughout the season.

Eurofins brings 70 people at each race to conduct the testing, with 15 test stations that complete around 7,000 tests every five days; first on Wednesday and then again on Sunday. The main reason for this is to ensure that all the key players such as drivers and mechanics that work on the cars

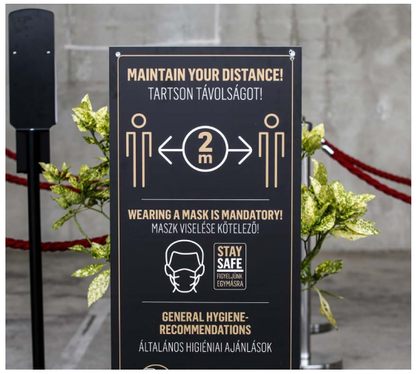
are tested early, to give the teams time to react if there is a positive case.

"If you have these people being tested on Friday or Saturday, before the qualifying, you put all the event in danger," says Mota. "We decided to test them at the latest on Wednesday, so you have the results on Thursday morning and then you have time to react and replace the whole team for the event on Sunday. The same thing applies if you test on Sunday, because you have the results on Monday morning you can plan for the next event, if it's the following week. So it's all about how you manage a suspected case or a positive case to keep the event running."

Each team has their own testing station behind their garage at the same distance so no team feels there is any unfairness from a sporting perspective. Other stations are situated at the main gate of the circuit for marshals. The test samples are then taken offsite to a laboratory in another country to be analysed, with the results appearing just a few hours later.

"In Austria we did all the testing in Germany and in Hungary we do all the testing using a lab in Vienna," says Mota. "That makes sense because from a political point of view you are not using resources from the country, and therefore not taking out testing capacity from the local society."

"EVERY DAY WE DID AN AVERAGE OF AROUND 500 COVID-19 SWAB TESTS"



Masks must be worn at all times in the paddock

There are plans to keep Eurofins as the main test provider for the season as it enables the FIA to keep track of each of the pre-tests and onsite tests between races, creating a 'health passport' for those who will be regularly attending.

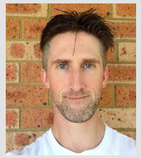
"Having the same test provider for the whole season, where they can provide a global agreement for anywhere, enables us to have a common database," explains Mota. "This means you can have a pre-test if you are coming from different countries. It allows us to restart the bubble or the cycle of three races, knowing the pre-test result before people join their bubble."

RETURN TO MOTOR SPORT GUIDELINES IN ACTION

As Formula One gets underway, other categories are now restarting worldwide including the British Touring Car Championship in the UK, Supercars in Australia, Stock Car Racing in Brazil, and national motor sport in Norway.

***AUTO+ Medical* spoke to some of the doctors on the front-line at these events to see how they are coping with the return of motor sport events in their country, and to know the type of restrictions they are under based on their country's current situation.**

AUSTRALIA



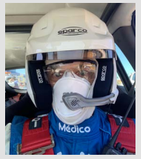
In Australia a lot of medical staff returned from helping out in hospitals at the height of the Coronavirus pandemic, notably those who were present at the Australian Grand Prix when F1 had to abandon the start of the season.

"For a short while, those of us working in medical careers diverted all of our attention to preparing our workplaces for the expected tidal wave of coronavirus patients," says Dr Matthew Mac Partlin, Deputy Chief Medical Officer Australian GP. "Thankfully, in Australia at least, that wave was not anywhere as big as in many other countries."

Once the government health department started to lift lockdown restrictions, the Australian Institute for Sport (AIS), in collaboration with Motorsport Australia, released its motorsport focussed Covid preventative guidelines.

"With two weeks' notice the first Supercars race was held at Sydney Motorsport Park in June, there were no spectators and no support categories," explains Mac Partlin.

BRAZIL



In Brazil, together with the Confederação Brasileira de Automobilismo (CBA) and FIA club members, protocol was determined based on the FIA's framework to restart motor sport.

"We based our own protocol on the FIA's one which facilitated our work, adapting it to our reality," says Dr Dino Altmann, President of CBA Medical Commission. "We first discussed it with our promoters and brought it to government authorities to have their approval and permission to restart."

"Restrictions are related to the course of pandemic in each region, state or city, pending on government permission," says Altmann. "A COVID-19 RT-PCR test is required for all participants of the events and a sanitary barrier is mounted at the entrance of every circuit to check everyone's health condition."

"It is strange to have an event with the participation of fewer people and no public but with time we will get used to it." adds Altmann. "Altogether it is great to be back to races in a safe way."

NORWAY

In Norway national motor sport training has been underway since the start of April, with motor sport events taking place since May.

"Norwegian associations and I were in discussions about the return and we opened fairly early as well," says Thomas Heggelund, Chief Medical Officer of Norwegian Motorsports Federation. "We made rules and regulations based on the national guidelines adapted to motor sports."

"There is a limit of 200 people on the track which means no spectators," explains Heggelund. "There are cohorts in the pit for the cars and crews, anti bact hand sanitizer must be used and least one meter between people."

However, the amount of motor sport events that have restarted is limited due to the impact on revenue that it would have got from entries and spectators.

"The really big problem is the limited entries in races, and no spectators, which means there is no profit in having races," says Heggelund. "They are all not financially viable, hence very few races are being held as motor clubs are making its money this way."

THE RETURN OF FANS

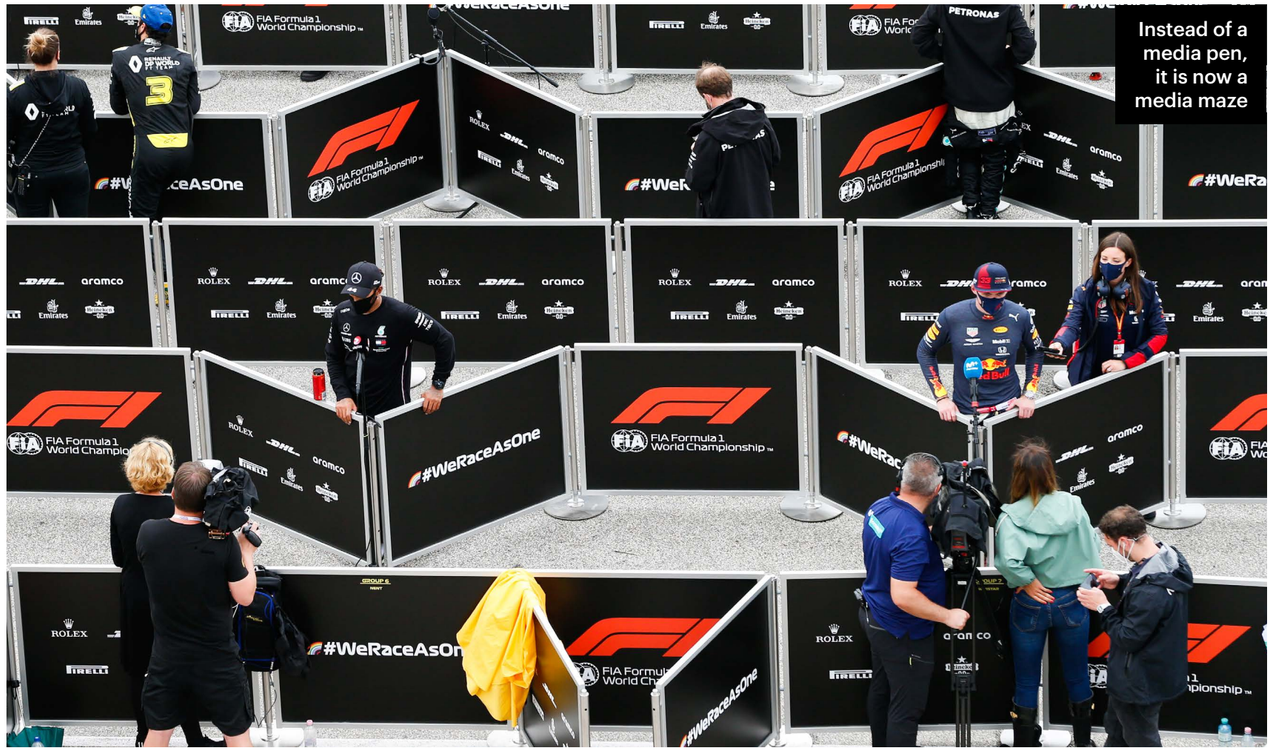
In recent months it has been commonplace to see fans celebrating sporting events from home, but with more races being added to the F1 calendar the prospect of fans returning to stands is gaining more traction as countries in Europe and Asia start to ease their lockdown restrictions.

The key thing from the FIA's point of view is not avoiding cases but being able to manage positive cases when they crop up. The challenge going forward will be to maintain the strict measures to ensuring the risk of transmission is still low, similar to how governments around the world are coping with the 'R' rate of infection number.

"People were discussing at the second race in Austria, the local promoter wanted to host 18,000 spectators," says Mota. "They will push to have the events as they used to be, and you have to negotiate again and say 'Listen, we were lucky. Don't push too much because we might have an outbreak!'"

There may also be limitations from governments in countries, as in some it is illegal to stage mass gatherings of more than a certain amount of people such as France, UK and Italy. For F1 races the responsibility of the wellbeing for spectators would be down to the local promoter of the race, rather than the championship or the FIA according to Saillant.

"It's another issue, to be honest it's not coming from the FIA or FOM, it's coming from the company of the hosting country," says Saillant. "Our regulations in France for example, it's impossible to have more than 5,000 people attending an open area sports event and currently in UK and Spain it's a similar situation. But the medical coverage of the FIA is only for the FIA family not for the spectators so it's down to the hosting country."



Instead of a media pen, it is now a media maze


Eurofins conducts the Covid-19 swab tests at each race

As for establishing motor sport calendars going forward it will largely depend on the individual situation of each country, and how Coronavirus outbreaks are being managed to ensure the safe running of each event.

"My opinion is that it will be easier to go to the to the east then to the west part of the world, because in the west part the virus is currently more aggressive especially in South America," added Saillant. "I think it would be impossible to go there this year."

Whatever happens in uncertain times F1 is being used as a testbed for global sport to restart, and with the strict guidelines outlined by the FIA that were created in collaboration with the WHO, everything is being done to ensure the safety of personnel at the track in the post-COVID era.

AUTO+MEDICAL FEATURES

PPE SENT WORLDWIDE

During the height of the coronavirus pandemic personal protective equipment (PPE) supplies experienced a global shortage caused by a rise in demand and panic buying. To help with the shortage the FIA teamed up with the International Federation of Red Cross and Red Crescent to ship out over 200,000 supplies of PPE consisting of masks and goggles, to hospitals and National Sporting Authorities throughout June and July. This graphic illustrates all of the individual countries that were sent PPE globally, to help front line workers in the fight against COVID-19.

GOGGLES

MASKS

MARIO ISOLA

PIRELLI HEAD OF F1 AND CAR RACING

Mario Isola is Pirelli's Head of F1 and Car Racing, overseeing the development of the 18-inch tyres that are set to debut in the championship in 2022. *AUTO+ Medical* spoke to him about the safety considerations that have been made for the 18-inch tyres, and about his life on the front line as a part-time ambulance volunteer in Milan.

AUTO+ Medical: How has the restart been for you?
Mario Isola: Strange! It's different from the normal situation, but I can say it has so far been successful. We had to work together with the FIA to implement all the COVID procedures, but they were working well since the first race in Austria. We had these few days mainly for communication with the teams because we have our engineers that are working in the back of the garage, they are not mixing with the team bubble and so they are a bit blind because they cannot see the car, they cannot see which tyres are being put on with the data, so we also need the support of the team's engineers and personnel in order to have to get the information we need that to do our job. But it is working well, considering the situation.

A+M: What have you done differently to ensure that your tyres have been delivered on time to the teams?
MI: First of all, we have a schedule that is agreed with the teams, in order to not have all the teams come into the fitting area at the same time. We have one team in each dedicated slot across two different fitting areas. We have a dedicated area for the delivery of the rims, we have another area for the collection of the fitted units, so there is no. We have our engineers in the back of the garage which is organised by the team, so again there is no mixing. We are following all of the procedures that have been implemented for the situation with the Covid test and all this kind of stuff. We have our dedicated area for catering, everything that has been organised for the teams is also valid for us, the difference is that we are a provider for all the teams so we have to pay additional attention to our procedures in order to avoid any mixing or any risk of spreading the virus if we ever suspect a positive case in our team. That didn't happen, but we will continue with this kind of attention, all of our engineers are wearing face masks as advised. We have also another dedicated area for analysing the tires after usage, that is reserved for our engineers that are here on track with us.

A+M: You are working on new 18-inch lower profile tyres, which have been brought into F2 this season and are set to be introduced to F1 in 2022. What are the safety considerations for them?
MI: We pay the utmost attention to safety and that means that before any tyres in a prototype are going on track, we run a number of indoor tests. During these years in F1 we implemented a new test, a new way of stressing the tyre in order to replicate what happens on track. It is very useful for us because F1 is an environment where our product is stressed at the highest possible level. That means that the methodologies that we developed for F1 are also useful to test our road the tires.

But consider that F1 tyres are working with the temperature that can go up to 150-160 degrees, in terms of forces acting on each tyre, we are talking about in some conditions you have a vertical load that is more than 1,000 kilos - can you imagine on a single tyre? That is quite a lot of weight, a lot of force acting, and it's the same for longitudinal forces like acceleration and braking, and for lateral forces. So we have the opportunity to test the tyres in the most stressful environment. The other point that it is good to highlight is the cooperation that we have with the teams, with vehicle models and with simulators. For this we provide them with a black box, which is a virtual tyre they can plug into their simulators, and thanks to that we can speed up the development, we can better understand the expected performance of the prototypes, and then we can test these prototypes with our indoor facilities to reduce the number of these that require the final validation on track. This is the future and the direction in which the automotive industry is moving. Recently we bought a simulator in Pirelli rather just relying on the simulator software of the teams. This is quite important because it's a good investment in terms of money, but it is really helpful in our development process.

> **"WE ARE FOLLOWING ALL THE PROCEDURES THAT HAVE BEEN IMPLEMENTED FOR THE SITUATION WITH COVID"**

A+M: How will these new tyres affect drivers physically?
MI: If I make a comparison with Formula 2 where we have a clear comparison because the cars are the same cars of last year, just the tires are different, we are running with a lap time that is similar to what we had last year. Consider that 18-inch tyre is a new product, we are just at the beginning of the development of this new product, the grip level is in line with 13-inch tyre. Being the sole supplier, it is not our priority to supply a tyre with a much higher performance, this is a difference between being in competition with other tyre suppliers compared to a sole supplier environment. Clearly we have to provide a tyre with some characteristics that are required by the promoter, talking about F2 the promoter is still asking for a high degradation tire or tires that enhance the show, encourage overtaking, so having a certain amount of degradation is clearly going in this direction. But the 18-inch tyre has proved to be more consistent anyway and the drivability is quite good. The feedback that I had from drivers

This year F2 cars introduced 18-inch tyres

after Austria was quite positive and we had also the opportunity to test the wet the tires on the Saturday. So it was a good test for our 18-inch product for both dry and wet. It is a different tyre, it is more reactive, in terms of drivability. In during our development tests last year, they reported or no differences in running on curbs compared to the 13-inch tyre, that was another aspect that we had to consider because with the low sidewall profile you expect that hitting the curb can be much harder with unbalancing the car and so on, so they reported that it was not a big issue. It was probably a bit worse in Austria because the kerbs are higher, so they had to pay attention to not hit the kerbs to badly, but it is still part of the competition. When we go to Monza with very high kerbs, with F2 they will have to pay attention not to cut the chicane too much because this can unbalance the car and make the driveability quite difficult, but it is the same with GT cars for example, they are using 18-inch tyres with a sidewall that is less part of the suspension compared to the 13-inch tyres, a very high side-wall is working as part of the suspension.

A+M: In future, tyre warmers are set to be banned in F1, what affect will this have?
MI: For F1 it was decided to move the ban on tyre warmers from 2023 to 2024, so at the moment we are working still with the blankets. I believe that is a sensible idea because we have to move step by step, so it is probably not good to introduce too many variables at the same time. We have a new technical regulation, new cars, new tires, for the first couple of years we will we will keep the blankets so we don't have another variable that is coming into this equation.

Isola has been a volunteer on the front line for 18 years

Then we will move a couple of years to the removing blankets. Obviously F1 is the pinnacle of technology, but it is also a sport and it is also a show, so we have to consider all these aspects and make a good mix to give spectators what they want to make the championship successful and also to keep the DNA of F1 to develop technology that is also the reason why Pirelli is in F1 for the long run.

A+M: You were on the front line as an ambulance driver during the height of the Coronavirus crisis in Italy, what was that like?
MI: I started many years ago when I was 18 years old, and this is now 32 years that I'm doing this as a volunteer. I started to do it because some friends were able to convince me who were doing this activity. At the beginning I was not 100% sure, but I did my training, passed the exam to be a volunteer. We don't have paramedics in Italy so I can I don't want to use the word paramedic, but we do First Aid with the ambulances and are a team of 150 volunteers. It's something different, it's a way to see something different from your normal life, keep your feet on the ground and understand that F1 is a nice environment, but outside the F1 bubble there is something else.

"VOLUNTEERING IS A WAY TO SEE SOMETHING DIFFERENT FROM YOUR NORMAL LIFE"

Especially in this period with the COVID-19 situation and unfortunately Milan was heavily affected by the Coronavirus, the situation was difficult, and I did do some shifts during this period, it was not easy not only because we had to implement different procedures like wearing protection with a mask, a visor, all this kind of stuff, but also different procedures. For example, we are not authorised to bring with the patient any friend or family member, because it was a protocol to avoid the spreading of the infection. And in some cases it was not an easy situation on the psychological side, because you had to take an old man or an old lady with this terrible coronavirus, they take him or her from the family without bringing anybody and it was maybe the last time they were going to see him.

So it was also not easy on the operational side and not easy on the psychological side, but luckily now the situation is much better we are back to more normal activity, but I will I will continue as I did in the last 30+ years or so. It's nice and I hope that with the Coronavirus maybe other people will decide to use their spare time to engage in these activities, not just the ambulance but you can be useful in many other activities and it's a way to learn something from your experience. Sometimes we say that being a volunteer is something that gives you more than what you give to the others, because at the end of the day this is true.

AUTO+MEDICAL FEATURES

WATER WORKS

Examining the importance of hydration in motor sport

The Abu Dhabi Desert Challenge is one of the toughest races for a driver to take part in physically. Over the course of five days, temperatures in the desert can often run up to 40 degrees centigrade and reach up to 67 degrees centigrade in the car.

That's why drivers must carry three liters of water with them to ensure they are hydrated during the race. Even so, lack of hydration is one of the main reasons for drivers having to withdraw from the event, according to event Chief Medical Officer Dr Sean Petherbridge.

"We get quite a lot of people who fall victim to simply not being hydrated enough and they get dizzy, make errors, or they simply stop in the desert and press their alarm," says Dr Petherbridge. "When we go to the aircraft and pick them up, we often find that hydration is the main issue."

Lack of hydration occurs when the body doesn't have enough water or salts to create blood volume, causing your heart rate to be higher and your cardiac output to be lower. The main area this affects is stamina and can

AUTO+MEDICAL FEATURES

sometimes be the reason as to why a driver falls off the pace during a race, as opposed to it being linked to anything mechanical with the car.

In the case of the Desert Challenge, it not only affects drivers but can also take its toll on the officials that run the event. Around 50 marshals are exposed to intense heat for up to 12 hours during the Abu Dhabi Desert Challenge, and research has found that maintaining good hydration levels can be a key mental performance aspect.

"We did some research into hydration in terms of fatigue and reaction times and we found that reaction times get worse, fatigue increases over the course of the event, and it does relate quite strongly to hydration," says Dr Petherbridge. "Where officials and competitors are dehydrated, then we find that performance degrades.

"The issue with a big event like that conducted in the sun is with the staff, particularly marshals who have to sit around the course for long periods. We give them shade, water, and encourage good nutrition. But often these are people who are volunteers, and they may work in environments where they're not adapted to being outside all the time."

At some event Dr Petherbridge and his colleagues have found a significant number of marshals needing treatment.

"In Bahrain, there was one event where we saw close to 100 or so needing treatment in one day," says Dr Petherbridge. "Thankfully we have good marshal support, which we back up with the medical center to ensure that the marshals and officials around the course are given water, rehydration solutions, and are checked on."

Lack of hydration can cause fitugue and limit reaction times

So how do athletes and officials maintain good hydration? According to Andy Blow who is the CEO of Performance Hydration, a company that focuses on sweat testing and the science of hydration, in normal non-stressful or non-challenging conditions drinking an adequate amount of water is all you need to do.

Where it gets a bit more difficult is when sweat loss becomes very high and you start to lose electrolytes in your sweat. Being able to maintain those levels is something drivers can often get wrong on the run up to big events.

"IN BAHRAIN THERE WAS ONE EVENT WHERE 100 PEOPLE NEEDED TREATMENT DUE TO DEHYDRATION"

"When I was working in Formula One many years ago, hydration was always talked about as a big issue," says Blow, who started out as a driver performance coach at the Benetton F1 team. "Drivers would habitually drink lots of water in the days before a race thinking that it would help them from a hydration standpoint, because that's the logical thing to do isn't it?"

"But if you do that with plain water, your body tries to maintain an equilibrium and you end up in a situation where you suffer from hypernatremia, which is where you pee out so much fluid that contains these electrolytes and you start with low blood sodium levels, which can be quite dangerous," explains Blow.

"A couple of hours before the race we usually get drivers to have an electrolyte drink which is about three times stronger than a regular sports drink in a fairly small quantity," says Blow. "The extra sodium in that drink gets pulled from the gut into the bloodstream, and then gives you a little bit of extra blood volume - which is what good hydration should do."

The main electrolyte that people lose in their sweat is sodium, but the amount of sodium that people lose can vary from person to person. This is why Precision Hydration tests the sweat profile of athletes to help them figure out whether they lose a tiny amount of sodium, a moderate amount, or really high amount.

For this they use at-rest Sweat Testing technology that can stimulate the sweat glands in the arm, then generate a sample which is run through a desktop analyser and tells you how much sodium concentrate is in the sweat.

"The range of sodium loss in sweat in humans is quite dramatic. At the lower end you might see someone losing 200 milligrams in every litre of sweat, and at the higher end someone could be losing 2,000 milligrams in every litre of sweat," says Blow.

Having worked with a number of teams and drivers up and down the Formula One grid, Precision Hydration has recently partnered with Williams to look at how hydration can affect every aspect of the team from the drivers to the mechanics and personnel.

"Williams were extremely interested because of what we could potentially bring to the pit crew and wider team, not just the drivers," explains Blow. "They want to look at it from an overall point of view, because those guys work

Drivers can lose up to three kilos in body weight from sweating

in pretty heavy clothing, it can be a very physical job, and often in extreme heat.

"And it's not just for the period of racing, they're working pretty hard in the days leading up to it before, during and after. You can lose an incredible number of electrolytes in short space of time and that's really what is the deterioration function that leads to lack of concentration, muscle cramps and overheating."

HEAT CHALLENGE

Typically, in F1 races such as the Singapore and Bahrain Grand Prix, drivers lose up to three kilos of body weight which is predominantly sweat. Blow says for every kilo of body weight a driver loses; it amounts to at least a litre of sweat.

"The vast majority of any weight loss in that period of time will be sweat lost, so if you lose a kilo of body weight, you're losing about a litre of sweat. I've worked with drivers who are easily losing three litres in a Grand Prix which is starting to get to the sort of level of fluid loss where performance can start to deteriorate.

"We would always expect drivers to dehydrate to an extent in your car, but they're not going to be able to drink as much as they lose. The idea is just to make sure that they do two things; get in the car optimally hydrated so they're not behind when they start, and then make sure that you can just stay above that critical line when performance starts to fall away, because after the race, they can obviously rehydrate and recover."

In other championships, drivers may also maintain that equilibrium throughout the races using other means such as onboard air conditioning, which Dr Petherbridge says is an effective trade-off between physiological performance and horsepower.

> **"YOU CAN LOSE AN INCREDIBLE NUMBER OF ELECTROLYTES IN A SHORT SPACE OF TIME"**

"Drivers in the rallies have resorted to running air conditioning units," says Dr Petherbridge. "They take a horsepower hit, but their physiological performance is slightly better because it's an endurance event. It's similar to aviation in that respect where the pilots are a component of the aircraft which has a failure rate accordingly. We should treat our drivers as components of the of the vehicle as a whole."

Australian V8 Supercars and IndyCar drivers have experimented with cooling shirts, where it takes away the heat during the race. Some F1 drivers also have also resorted to cooling vests, which they wear on the grid before the race to help manage their temperature.

"If you look at some of the research of cognitive performance, and body temperature, it goes down when your body temperature gets above 38 degrees centigrade," adds Dr Petherbridge. "It's not unusual to find body temperatures in race car drivers who are half an hour into an event and up to something like 38 to 38.5 degrees centigrade because of the heat of the physical activity of racing."

This is where good hydration becomes more than just a matter of performance but also a safety issue. The simple solution of drinking the right amount of fluids can ensure that drivers, team members and officials keep themselves and others safe on and around the track.

Credit: Chris Schotanus

INSIDE THE...

ZANDVOORT MEDICAL CENTER

AUTO+ Medical takes a look at the facilities and equipment inside the newly build medical center at Zandvoort, as it prepares to host its first Formula One race at the circuit in 36 years.

For the first time in 36 years Formula One will make a return to Zandvoort in the Netherlands, for the Dutch Grand Prix in 2021. The track has undergone significant changes since the Grand Prix was last held, the most notable additions being two steep 18-degree banking corners.

There is also a new state-of-the-art medical center which will house the 35-strong medical team, which is comprised of 15 doctors, a trauma surgeon, an emergency physician, a family doctor with expertise in car racing, and the others are nurses who work in the pre-hospital environment.

Located in the in-field section coming off Turn 14 before the pit straight, it was built by De Groot Vroomshoop in consultation with the circuit's architect Dromo and Chief Medical Officer, Erik Koolen.

"It was a great opportunity for us because we could make a wish-list of whatever we wanted," says Koolen.

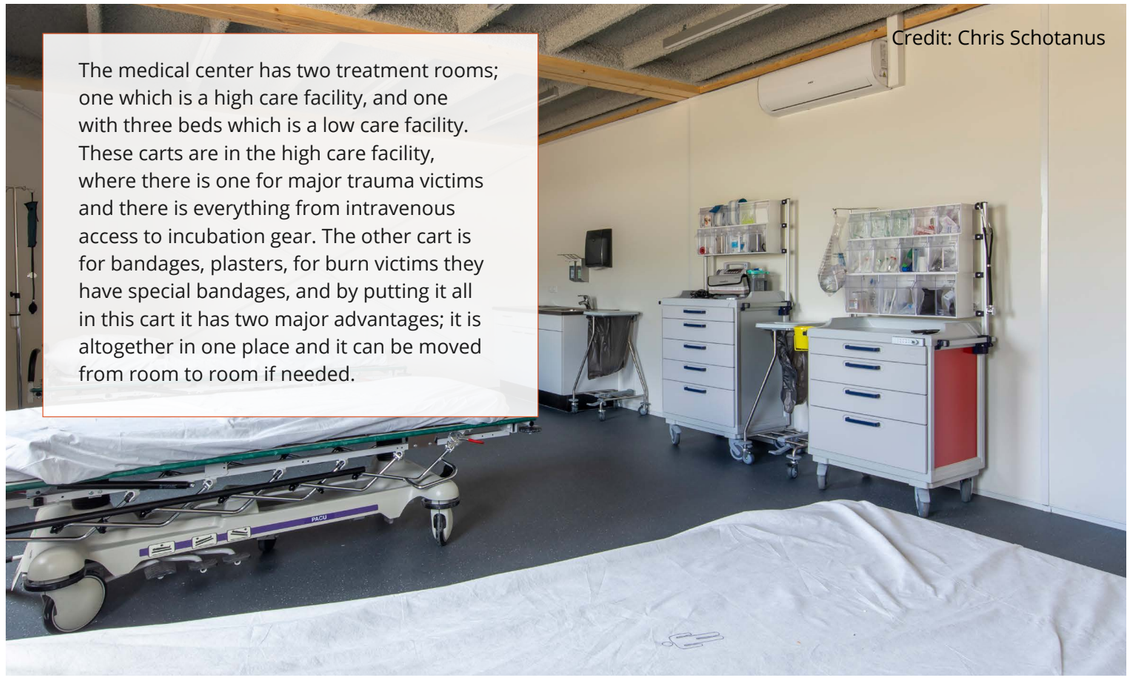
Part of the process for Koolen was taking into consideration what F1 require to stage the race, including the location of the new building in relation to the track and creating space for a helicopter to land.

"I had to talk to the architect and figure out where we can locate the medical center and where can we put the helicopter platform," says Koolen. "I had to talk to one of our other doctors who said, 'It depends on the type of helicopter' and he showed me the common type that is used and that's what we built it for."

Zandvoort's unique banking's also posed a challenge and required a new protocol incase an ambulance is needed to stop on them and use a stretcher in the event of an emergency.

"The architect who built them came to me and asked if it was possible to drive an ambulance on a banked corner, which we can manage," says Koolen. "But is it possible to stop an ambulance, to park it on a steep banking corner like this?

"I had to talk to some of our ambulance drivers and they said it was possible, but now we have to train ourselves because when you get out of the ambulance you have a procedure, and if you need to put someone on a gurney on a banked corner that's 18-degrees it's really, really steep," explains Koolen. "These are things most circuit designers don't think about, how to accommodate all of the medical facilities, and other things you have to take into account."

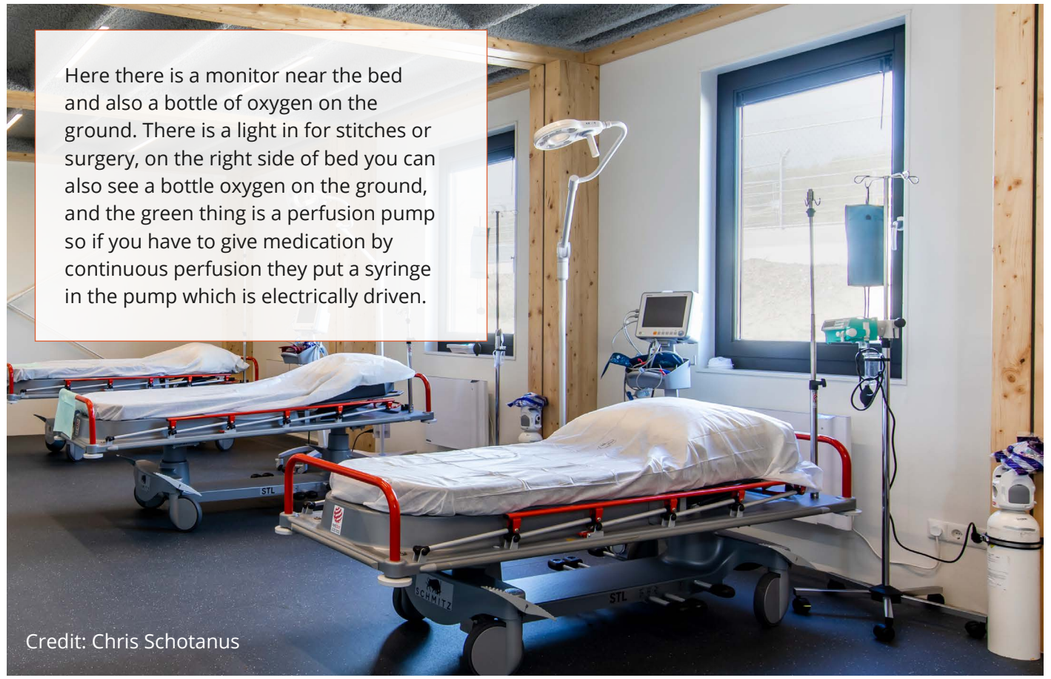


The medical center has two treatment rooms; one which is a high care facility, and one with three beds which is a low care facility. These carts are in the high care facility, where there is one for major trauma victims and there is everything from intravenous access to incubation gear. The other cart is for bandages, plasters, for burn victims they have special bandages, and by putting it all in this cart it has two major advantages; it is altogether in one place and it can be moved from room to room if needed.

Credit: Chris Schotanus

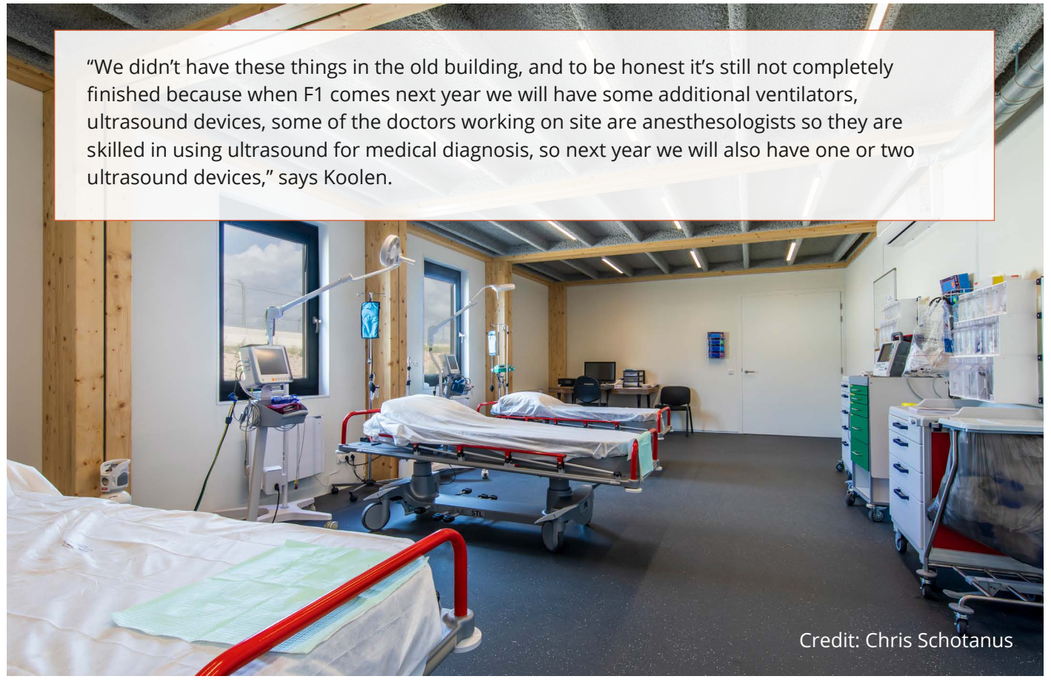
This is the low care facility, here there are two carts which are similar to the ones in the high care on the left-hand side, but on the right hand side there is a cart for trauma, and in the middle there is one for CPR which has a defibrillator if needed.

Credit: Chris Schotanus



Here there is a monitor near the bed and also a bottle of oxygen on the ground. There is a light in for stitches or surgery, on the right side of bed you can also see a bottle oxygen on the ground, and the green thing is a perfusion pump so if you have to give medication by continuous perfusion they put a syringe in the pump which is electrically driven.

Credit: Chris Schotanus



“We didn’t have these things in the old building, and to be honest it’s still not completely finished because when F1 comes next year we will have some additional ventilators, ultrasound devices, some of the doctors working on site are anesthesologists so they are skilled in using ultrasound for medical diagnosis, so next year we will also have one or two ultrasound devices,” says Koolen.

Credit: Chris Schotanus

THE ROAD BACK:

JEHAN DARUVALA

Towards the end of the 2019 season, Formula 2 racer Jehan Daruvala sustained a serious knee injury while he was playing football as part of his training regime. The Indian driver tore both his ligaments and damaged his meniscus. The incident subsequently forced him to miss the final event on the FIA Formula 3 calendar, the Macau Grand Prix, as he had to have surgery to his right knee close to the race. He eventually returned to the car at the F2 pre-season test at Bahrain in February, where he impressed enough to be signed by the Red Bull F1 team Junior Driver Programme. He recently took part in the three rounds at Austria and Hungary with Carlin, achieving three top 10 positions. AUTO+ Medical speaks to him about his injuries and recovery.

AUTO+ Medical: How did you get injured?
Jehan Daruvala: I was playing football with my friend back home in Mumbai in India and basically the ground was a bit wet, my knee got stuck in the ground, and my leg twisted. I heard quite a big 'pop' in my leg, and I was in excruciating pain for the first couple of minutes, but then it eased off. I went to hospital in Mumbai where I got my MRI done as soon as possible, and the result was that I tore both my ligaments and I also damaged my meniscus, so it was a big impact for my knee.

A+M: Where did you get the MRI scan?
JD: I went to Breach Candy Hospital in Mumbai, which I know quite well. I got the scan as soon as possible on the same night, then I got in touch with a top surgeon in India, Dr Dinshaw Pardiwala. I got my surgery done two days after my accident on my right knee, and I was home four to five days after that.

A+M: What sort of treatment did you have for it?
JD: After damaging my meniscus, the surgeon suggested I go to rehab but don't rush into things. I had protocol which said that I couldn't put my foot down for six weeks after the surgery, so there was not much I could do rehab wise except do some exercises for my leg. But after those weeks I started to do proper intensive rehab at a clinic like 15-20 minutes from my house back home. For this I just worked on my leg, it took a long time to walk normally and still after seven or eight months now I'm still not allowed to run on my leg. It was all about doing the fitness stuff that I required for driving my car and not pushing into stuff that could lead to damaging my knee again. Now I'm almost clear to do all exercises, although not too many open chain exercises with heavy weights. But running or jumping are all the main things that I still have to avoid. I also have a nutritionist and I take Optic Turmeric every morning along with my other vitamins, as that helps cleaning up the joints or ligaments quicker.

A+M: Is there a timeframe on when you'll get fully fit?
JD: I feel pretty fit right now, but I'm still not clear to run. I think regarding the meniscus, apparently it takes really long to heal and you don't want to risk putting that in jeopardy, but right now I can do most things, such as cycle, row and swim.

Daruvala took three top 10 positions in Austria and Hungary

A+M: Was that the reasons you couldn't contest the Macau GP?
JD: That was a month and a half after surgery, so a definite 'no' from the surgeon. I had to wait at least three months before I could step back in a car. Luckily the race car is not too harmful or demanding on the knee itself, but there are other G-forces you have to look out for, and I was clear to drive a race car after three months.

Photo Credit: Jehan Daruvala Instagram

"ITS BETTER TO FOCUS ON THE REHAB SIDE AND MAKE SURE YOU'RE FULLY FIT BEFORE GETTING BACK IN THE CAR"

A+M: What was it like getting back into the car?
JD: Well the first time I was back it was at the F2 test in Bahrain, and to be honest it went quite smooth I didn't really feel any trouble from the outing. At that time, I was just struggling a bit with full bending of my leg, so getting out of the car within the timeframe that we have to do was a bit hard then. Obviously now it's been another three months since then, so my knee is practically back to normal.

A+M: What sort of advice do you have for drivers that suffer similar injuries?
JD: It's a pretty tough situation to be in when you're competing in a high level of sport. Injury like this is a major setback. But I think the main thing is to just focus on getting better as soon as possible and listening to the surgeon and the people who give you the advice, because it's easy to want to get back to sport, playing sport early, but it leads to more injury. So even though it's hard at the time, it's better to focus more on the rehab side and make sure you're fully fit and ready before you get back.

SCIENTIFIC ARTICLE:

ESTIMATED CRASH INJURY RISK AND CRASH CHARACTERISTICS FOR MOTOR SPORT DRIVERS

The crash dynamics in motor sport can differ vastly to those on the road. This literature review looks at the different crash chracteristics in motor sport compared to road cars.

Authors: John P. Patalak, Matthew G. Harper, Ashley A. Weaver, Nicole M. Dalzell, Joel D. Stitzel.

1. INTRODUCTION

Accidents or unintentional injuries are continually listed among the top five causes of death in the United States. An estimated 7.2 million police-reported motor vehicle crashes (MVC) accounted for 37,461 fatalities in the United States during 2016 (Heron, 2018). While traffic fatalities have followed a general downward trend over the last several decades, when adjusted for miles travelled, opportunity for driver safety improvements remain (NHTSA, 2019). Motor sport participants present a unique subset of drivers subjected to MVCs. While driver safety has always been a primary goal in motor sports, during the first few years of the twenty-first century a large and deliberate effort to advance driver safety in the National Association for Stock Car Auto Racing, Incorporated (NASCAR®) was undertaken. Notable advancements resulting from this effort included compulsory use of head and neck restraint devices, introduction of the Steel and Foam Energy Reduction (SAFER) Barrier and advancements in driver restraint systems. The SAFER barrier has been documented to reduce peak chassis accelerations by 30–80 percent. These reductions in peak acceleration are paired with increased crash time durations, resulting in very similar change in velocities (ΔV) between similar SAFER and non-SAFER outer wall impacts (Bielenberg et al., 2004). Together these changes trans- formed the safety of motor sports. The research supporting these large safety advancements benefited from the implementation of the NASCAR medical liaison program with advanced driver incident record keeping and the deployment of Incident Data Recorders (IDR) by NASCAR in 2002. These programs have evolved and grown since 2002 and continue currently.

While the motor sport restraint system is unique to its environment, it shares with passenger vehicle restraint systems a common goal of successful occupant protection. During frontal impacts, a seven- or nine-point seat belt restraint system, head and neck restraint, full face helmet, all-belts-to-seat containment seat and energy absorbing toe-board foam provide restraining forces to load-bearing areas of the driver's body. During side impacts, the driver's containment seat with head surround provides the primary means of restraint via lateral supports at the driver's head, shoulder and pelvis. Bilateral leg extensions and a padded knee knocker complement the seat lateral supports and provide lower extremity restraint. The rigidly mounted seat provides occupant restraint during rear impacts. The development and effectiveness of this restraint system has been presented in previous publications (Melvin et al., 2006; Patalak et al., 2013; Patalak et al., 2015; Patalak and Melvin, 2008; Patalak and Stitzel, 2017; Smith et al., 2011; Somers et al., 2011).

Motor sport crash events are complex and driver restraint systems are unique to the motor sport environment. NASCAR crash and medical datasets provide an opportunity to assess crash statistics and the specific relationships between motor sport crash characteristics and driver injury. A limited overview of portions of the NASCAR crash data has previously been published which included estimates of mileage covered, full time driver participation and a summary of lower extremity injuries (Patalak and Stitzel, 2017). In order to generate overall estimates of driver injury, which spans multiple seasons, this study expands that previous research by generating driver injury risk curves using all driver injuries, across eight race seasons of two racing divisions. Weaver et al., developed risk curves to estimate driver injury risk using vehicle IDR and other factors as inputs (Weaver et al., 2015). These relationships can provide guidance and insight for at-track emergency response, driver triage and treatment protocols as well as influence future expenditures on motor sports safety research (Bahouth et al., 2004; Champion et al., 2004; Kononen et al., 2011).

2. METHODS

Monster Energy NASCAR Cup Series (MENCS) & NASCAR Xfinity Series (NXS) vehicle chassis acceleration data is recorded during a crash by the IDR. The current IDR, implemented in 2011, was supplied by Diversified Technical Systems, Inc. (DTS, Seal Beach, CA) and records tri-axial acceleration at 10kHz (Patalak et al., 2011). The IDR is rigidly mounted to the vehicle left frame rail, near the driver's left knee. The IDR utilizes an 8G X (longitudinal) or 18G Z (vertical) or 12G Y (lateral) trigger threshold which must be maintained for at least 14 consecutive samples (1.4ms). When this threshold is satisfied, a recording for 20s is logged. Typical IDR downloads are only two seconds, but the full 20s may be downloaded for atypical events such as rollover or when multiple impacts are observed. During each MENCS and NXS event, inspectors survey and catalogue each vehicle's driver restraint system prior to the race. When on-track crashes occur, incident reports are created in the NASCAR Safety & Crash Analysis (NSCA) database, which includes IDR data, crash information, vehicle pictures and restraint survey information.

"MOTOR SPORT CRASHES ARE COMPLEX AND DRIVER RESTRAINT SYSTEMS ARE UNIQUE TO MOTOR SPORT"

Similarly, when drivers present at a racetrack Infield Care Center (IFCC) they are triaged, treated and released or transported as determined by the IFCC medical staff. The NASCAR Medical Liaisons update and maintain driver medical records during NASCAR events, including the addition of Association for the Advancement of Automotive Medicine (AAAM) Abbreviated Injury Scale (AIS) scores. This coding system is used to anatomically classify and capture the severity of injuries. There are eight anatomical body regions (head, face, neck, thorax, abdomen, spine, upper extremity and lower extremity) and six levels of severity (minor = 1, moderate, serious, severe, critical and maximum/untreatable = 6). AIS 2005 was used for all driver records in this study (Association for the Advancement of Automotive Medicine, 2007).

Combining the NSCA and IFCC databases provides an opportunity to evaluate and estimate driver injury risk as it relates to specific crash attributes, such as principal direction of force (PDOF), ΔV, peak acceleration or others. While IDR data is available from 2002, the season ranges of 2011–2018 were strategically chosen for this study. A 5th generation vehicle chassis, first introduced in the MENCS series in 2007, was also utilized by the NXS series since 2011. Major improvements to the driver restraint system including head and neck restraints, full face helmets, reinforced driver containment seats and anti-sub-marine seat belts were all implemented between 2005 and 2011. Lastly,

AUTO+MEDICAL SCIENCE

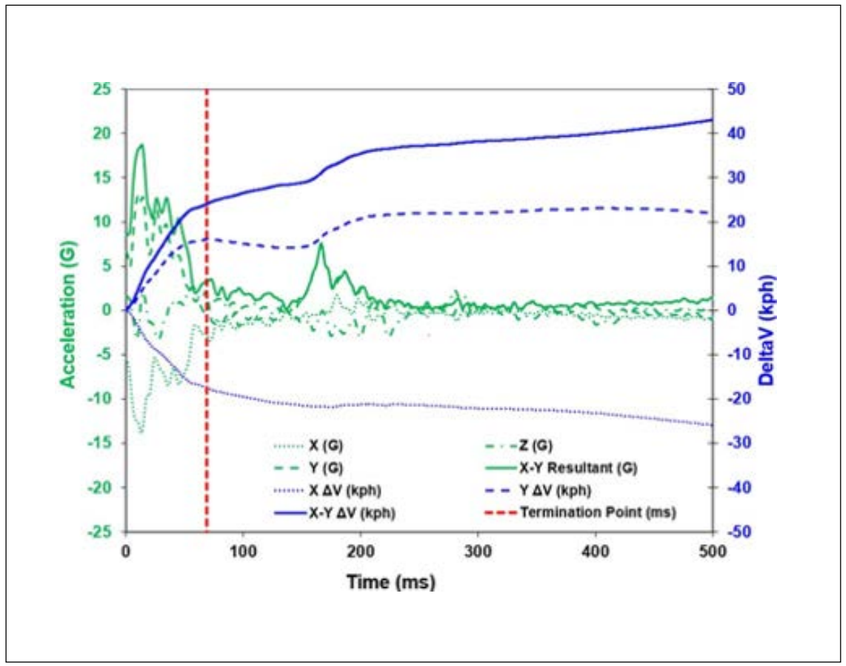


Fig 1. Visual depiction of how crash duration was calculated: dashed red vertical line indicates when the average acceleration for a 15-millisecond window of each IDR channel and the resultant of the longitudinal (X) and lateral (Y) were simultaneously < 3G (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

starting in 2002 deployment of the SAFER barrier at all MENCS tracks was complete by 2005. While safety improvements continued since 2011, this study season range represents the modern vehicle chassis, driver restraint system and track barriers.

2.1. NSCA DATABASE PROCESSING

Post-impact NASCAR inspectors attach the IDR data file to a unique incident report within the NSCA database. For this study, all MENCS and NXS car IDR data for the 2011 through 2018 race seasons was used. This included 2527 total incident reports (1578 MENCS + 949 NXS). MATLAB Version 2018b (The MathWorks, Inc., Natick, MA) was used to process the incident report IDR data files. Crash pulses were determined to be complete when the absolute value of the average acceleration for a 15-millisecond window of each IDR channel and the resultant of the lateral (Y) and longitudinal (X) accelerations) were simultaneously < 3G. Fig. 1 shows an example of this termination point, which is highlighted by the dashed red vertical line. This time duration was used for calculations of ΔV and the PDOF. For this study the longitudinal, lateral and vertical vehicle axes are denoted by X, Y and Z respectively.

Occasionally, non-crash events are recorded by the IDRs. These may include pit stops, chassis contact with racetrack transitions between the apron and banked surfaces, or even removing the IDR from the vehicle. Each IDR is installed in a vehicle mounted shoe. This shoe contains a magnet used to indicate to the IDR its presence in a vehicle. This system is used to prolong the limited self-contained IDR battery power. Occasionally, after the conclusion of the race event, the action of removing the IDR from the shoe results in an event being logged. Trivial and non-crash related IDR data files which had a ΔV less than 8kph (5mph) were removed.

Each IDR data file was further processed to determine if additional crash events occurred beyond the 3G crash pulse end point, using the IDR trigger thresholds. If additional crash events were present in a data file, the crash event with the largest ΔV was used to represent the data file. The total number of crash events were tabulated for each data file as well. When a NASCAR inspector completes a NSCA incident report a field for rollover is included. This field indicator was used to remove incident data files associated with rollover incidents. These processing steps produced 2065 individual incident reports with associated IDR data files. The PDOF of each of these IDR data files was calculated using the following process. A linear regression line was fit to the longitudinal versus lateral ΔV line for the duration of the crash as determined by the 3G criteria. The angle of the linear regression line was then calculated and used as the resulting incident PDOF.

2.2. MEDICAL RECORD DATABASE PROCESSING

IFCC reports for the MENCS and NXS seasons of 2011–2018 were combined from the medical record database for all driver incident re- ports and injuries. This final dataset included 1738 unique medical record incidents. For the NASCAR driver medical record keeping, all driver injuries and/or diagnoses occurring while a driver is in the vehicle are included in the incident medical database without regard to if a crash occurred. NASCAR medical liaisons also conduct post-event follow ups with all drivers seen in the IFCC. These follow up notes occasionally contain additional diagnosis or injury information. The following steps were conducted to process the medical record data.

“ON AVERAGE NASCAR EXPERIENCED A CRASH RATE 136 TIMES LARGER THAN PASSENGER VEHICLES”

IFCC staff will always triage/treat any driver at any time for any reason. Drivers are able and encouraged to also self-report at any time to the IFCC for evaluation. Across the seasons of NASCAR competition on which this study is based, the policy which dictated when a driver must be evaluated at the IFCC evolved, which resulted in an increase of medical record reports in later years. Initially, if a post-crash vehicle could be driven by the driver into the garage area, that driver was not required to be triaged at the IFCC. Later, this policy was updated to require all drivers whose vehicles could not continue in the event to be triaged at the IFCC. For the purpose of this study if a driver was involved in an on-track crash with a NSCA incident report created, but for which there was no corresponding medical record, the incident was categorized as non-injurious.

Of the 1,738 total medical record incidents, 415 were categorized as containing an injury. The remaining 1,323 records were categorized for injury as “No Injury – MVC” and “MVC No New Complaints” for follow up. Of the 415 cases of injury, 129 included one or more AIS scores. After a manual review, the follow up

column was searched for the following key words: Soreness, Pain, Stiff, Headache, Tender, Abrasion, Spasm, Contusion and Strain. This produced 65 additional findings of a diagnosis or injury based on follow up. An AIS score of 1 was assigned to contusions, abrasions and sprains identified in the follow up notes when the body region was identifiable. A category of sub-injury, meant to encompass clinical signs and symptoms that would not necessarily themselves be diagnosed as injuries, was created in order to categorize diagnoses. This category included generalized soreness, headache, neck soreness, stiff neck and others. Where recorded details permitted, these sub-injury diagnoses were attributed to a body region. Generalized soreness and/or stiffness was categorized as sub-injury and attributed to the whole body.

There is not a distinct field in the medical database which indicates driver injuries which are solely associated with or due to a NSCA reported vehicle crash. Many medical records contained potential non-crash related injuries or diagnoses including nausea, CO intoxication, burns, blisters, smoke inhalation, dehydration, foreign body in eye, heat exhaustion, generalized fatigue and generalized cramping.

2.3. NSCA AND MEDICAL RECORD ASSEMBLING

The processed NSCA dataset contained 2065 incidents or unique events. The medical record dataset contained 480 unique injury and sub-injury incidents. Each NSCA incident is unique to a driver/vehicle. For example, if three vehicles all collided with each other simultaneously on-track, each vehicle represents a unique NSCA incident, with a unique IDR data file and a unique driver

“RIGHT LATERAL IMPACTS WERE FOUND TO HAVE A LOWER INJURY RISK THAN ALL OTHER PDOFS”

medical record. Using the driver full name, incident date and racetrack name columns the two datasets were merged by row to match injury records to corresponding IDR data files. This resulted in 246 injury records being matched to specific IDR data files. The remaining 234 injury and sub-injury records were manually reviewed to confirm no IDR data file matches were available. The unmatched injury records were categorized as non-crash related. For the purposes of this study, when non-crash related injuries were

Equation	Probability of	Coefficients - description	Estimate	P-Value	Standard Error	AUROC	Deviance Reduction (%)
1	Sub-injury or AIS 1+	βo - Intercept	**−4.565**	< 0.001	0.250	0.80	19.5
		β1 – XY Res ΔV (mph)	**0.050**	< 0.001	0.007		
		β2 – XY Res PeakG	**0.057**	< 0.001	0.010		
		β3 - Right	**−0.806**	< 0.001	0.161		
		β4 - # of Impacts	**0.340**	0.007	0.125		
2	AIS 1+	βo -Intercept	**−4.235**	< 0.001	0.201	0.79	16.8
		β1 – XY Res ΔV (mph)	**0.045**	< 0.001	0.007		
		β2 – XY Res PeakG	**0.054**	< 0.001	0.011		
		β3 - Right	**−0.718**	< 0.001	0.169		
3	Thorax AIS 1+	βo -Intercept	**−6.988**	< 0.001	0.808	0.87	27.2
		β1 – XY Res ΔV (mph)	**0.088**	< 0.001	0.016		
3	Upper Extremity AIS 1+	βo -Intercept	**−4.651**	< 0.001	0.393	0.74	10.9
		β1 – XY Res ΔV (mph)	**0.056**	< 0.001	0.010		
3	Lower Extremity AIS 1+	βo -Intercept	**−6.449**	< 0.001	0.733	0.80	18.6
		β1 – XY Res ΔV (mph)	**0.073**	< 0.001	0.016		

Table 1: Model Coefficients. Predictors with coefficient estimates (p < 0.05) are shown in bold.

the sole injury present for a NSCA crash, the crash was listed as non-injurious.

2.4. INJURY RISK MODEL

The resultant of the lateral and longitudinal change in velocity (XY Res ΔV), peak resultant of the lateral and longitudinal acceleration (XY Res Peak G), Z peak acceleration, number of impacts and impact duration were calculated for each data file. For use in NASCAR, the model was generated with XY Res ΔV in miles per hour (mph). Figures have been converted to International System of Units (SI units), except Figs. 6 and 7. An indicator variable was created for PDOF using four binned categories of 90 degrees: Frontal, Right, Rear and Left impacts, as shown in Fig. 4. These quadrants maintained the visible incident clusters as shown in Fig. 4. Multiple logistic regression modelling in R

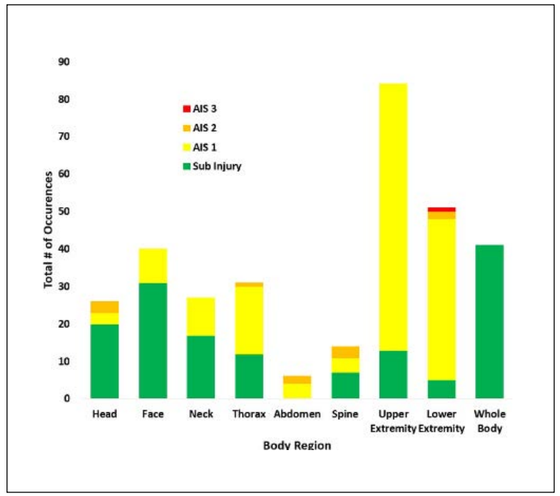


Fig. 2. AIS Scores by Body Region & Severity.

was used to produce five injury risk curves (R Core Team, 2019). Logistic regression assumes the response variable is a binary random variable (injury or no injury) and was modelled with a Bernoulli random distribution with P probability of injury. Table 1 - Model Coefficients. Predictors with coefficient estimates ($p < 0.05$) are shown in bold.

Manual exploratory data analysis was conducted, and linearity was checked with empirical logit plots and deviance comparisons. Impact duration was initially included as an IDR generated proxy for whether a crash involved the SAFER barrier but was not included in the final model due to large multicollinearity with XY Res ΔV. Inclusion of an interaction between XY Res ΔV and XY Res Peak G was also assessed. However, this interaction lowered model deviance R2 and increased the model Akaike information criterion (AIC) and was therefore not included in the final models. The Z peak acceleration, frontal, left and rear impact PDOFs were not

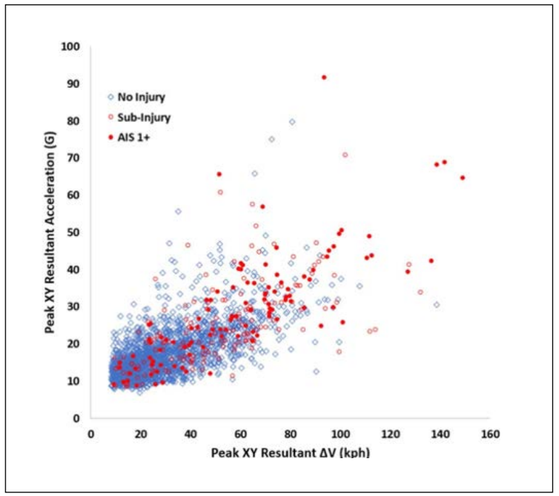


Fig. 3. Non-Injury, Sub-Injury & AIS 1+ Injury Plot.

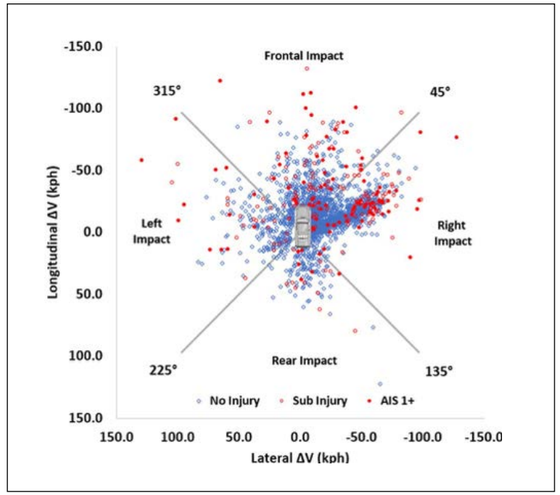


Fig. 4. Non-Injury, Sub-Injury & AIS 1+ Injury PDOF Plot.

significant predictors and were removed from the final models. As shown in Table 1, a binary indicator for Right PDOF is included in the final model. If the PDOF ≥ 45 and < 135 degrees then Right is 1, otherwise Right is 0. Nested likelihood ratio tests and best subset selection were also used to confirm predictor selection for Eqs. (1 and 2) models. Best subset selection was performed with the best glm function in R (A.I. McLeod and Xu, 2018), using AIC and Bayesian Information Criterion (BIC) as metrics to compare models. Both criteria resulted in the same predictor selection. Eq. (1) shows the final model for the probability of driver injury risk for any sub- injury or AIS 1+ Injury using all 2065 available cases.

$$P(\text{sub injury or AIS 1+ Injury}) = \frac{e(\beta o+\beta 1(XYResΔV)+\beta 2(XYResPeakG)+\beta 3(Right)+\beta 4(\#ofImpacts))}{1 + e(\beta o+\beta 1(XYResΔV)+\beta 2(XYResPeakG)+\beta 3(Right)+\beta 4(\#ofImpacts))} \quad \textbf{(1)}$$

The same methodology was used to develop a model for the prob- ability of driver injury risk for any AIS 1+ Injury also using all 2065 available cases, but with the sub-injury cases designated as non-in- jurious, which is shown in Eq. (2). The number of impacts was no longer a significant predictor.

$$P(AIS1+Injury) = \frac{e(\beta o+\beta 1(XYResΔV)+\beta 2(XYResPeakG)+\beta 3(Right))}{1 + e(\beta o+\beta 1(XYResΔV)+\beta 2(XYResPeakG)+\beta 3(Right))} \quad \textbf{(2)}$$

Previous research has developed injury risk curves for specific body regions and AIS severities using frontal impacts from the National Automotive Sampling System Crashworthiness Data System (NASS- CDS) (Weaver et al., 2015). Using only frontal impacts (per Fig. 4) and the XY Res ΔV, body region specific injury risk curves were developed where sufficient injury cases were present and are shown in Eq. (3).

$$P(AIS\ 1+\ Injury) = \frac{e(\beta o+\beta 1(XY\ Res\ ΔV))}{1 + e(\beta o+\beta 1(XY\ Res\ ΔV))} \quad \textbf{(3)}$$

Peduzzi, et al. demonstrated that a small outcome event to in- dependent variable ratio, or events per variable (EPV) may produce biased or inaccurate regression coefficients. An EPV of 10 was high- lighted as a guideline for a sufficient ratio (Peduzzi et al., 1996). Eq. (1) had an EPV of 60.5 and Eq. (2) had an EPV of 36. Eq. (3) had EPVs of 11, 29 and 10 for thorax, upper extremities and lower extremities, respectively.

3. RESULTS

Fig. 2 shows the matched injury records by AIS body region and severity along with the sub-injury and whole-body categories. Figs. 3 and 4 show the AIS 1+ injury, sub-injury and non-injury incidents plotted against IDR generated attributes.

Fig. 5 shows the annual totals for No Injury and the AIS 1+ & Sub-injury crashes. The annual average XY Res ΔV and average XY Res Peak Gs for non-injury and AIS 1+ & Sub-injury incidents are also shown.

Across all race seasons in this study the overall average XY Res ΔV was 34.4 kph (21.4 mph) and the overall average XY Res Peak G was 19.0 G for an average of 258 crashes per season. The overall average XY Res ΔV for non-injurious incidents was 31.6 kph (19.6 mph) versus 55.5 kph (34.5 mph) for AIS 1+ & sub-injury incidents. The overall average XY Res Peak G for non-injurious incidents was 17.9 G versus 26.9 G for AIS 1+ & sub-injury incidents.

In order to generate Figs. 6 and 7 XY Res ΔV ranged from 0 to 100 mph with 101 samples. XY Res PeakG was calculated using XY Res PeakG = 0.453 (XY Res ΔV). 0.453 was the slope of a linear regression applied to the Fig. 3 data after centering. 95 % confidence intervals for all injury risk curves were computed using the standard error.

Specific body region models shown in Figs. 8–10 were limited to a single predictor of XY Res ΔV for comparison purposes to prior re-search. The final model coefficient estimates, associated P-values, standard error, Area Under the Receiver Operating Characteristic (AUROC) curve and percent reduction in deviance (between null and residual) are shown in Table 1.

Model curves for Eqs (1 and 2) are shown in Figs. 6 and 7, respectively. Model curves for Eq. (3) are shown in Figs. 8–10. The dashed lines represent the 95% confidence intervals for each curve. Weaver, et al. body region specific curves for NASS-CDS (passenger cars, light trucks and vans) belted frontal occupants are included for comparison purposes in Figs. 8–10.

As shown in Table 1 and Figs. 6 and 7, in-creasing XY Res ΔV, XY Res Peak G and the number of impacts during a crash event all in-crease estimated driver AIS 1+ injury and sub-injury risk for the Eq. (1) model. After account-ing for the other predictors in the model, right

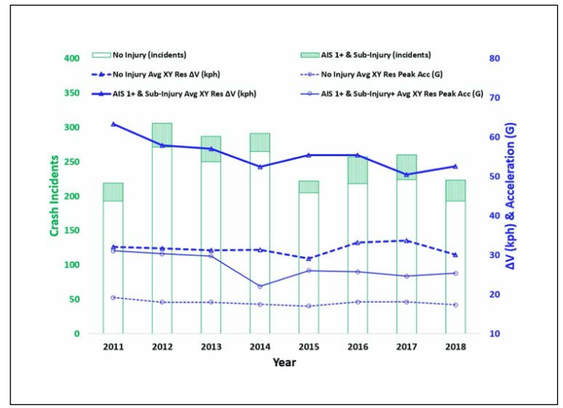


Fig. 5. Annual IDR data summary: Total incidents of Non-Injury & Sub-Injury/Injury bars (primary vertical axis) with overall annual means for ΔV and peak acceleration of non-injury & Sub-Injury/Injury incidents (secondary vertical axis).

lateral impacts were found to have a lower estimated injury risk than all other PDOFs for Eqs. (1 and 2) models. As shown in Table 1 and Figs. 8–10, increasing XY Res ΔV during a crash event increased driver AIS 1+ injury risk for Eq. (3) models.

This dataset represents NASCAR race car crash characteristics and driver restraint system performance which provides an opportunity for comparisons to passenger vehicle systems and statistics. The 2011–2018 race season dataset of MENCS and NXS crashes includes 577 race events. There were 39 MENCS races (including 3 non-point races) per year, and 33 NXS races per year, except 2011 which had 34 races. Using NASCAR Timing & Scoring data, the total mileage (practice, qualifying and race) by all drivers in these 577 events is 8,096,475 miles. For these 577 races, the final dataset includes 2065 unique crash IDR data files (excluding rollovers/atypical crashes and trivial/non- crash impacts) with 246 AIS 1+ and sub-injury findings.

The National Center for Statistics and Analysis (NCSA) of the National Highway Traffic Safety Administration (NHTSA) annually publishes summaries of passenger vehicle crash statistics. While the NHTSA National Automotive Sampling System (NASS) General Estimates System (GES) was replaced in 2016, statistics from 2011 through 2015 were reviewed and compared for this study. NCSA often uses 100 million vehicle miles travelled (100M VMT) to normalize passenger vehicle travel exposure-based statistics. Police-reported crash rates (crashes per 100 VMT) and injury rates (injury per crash) for passenger vehicles and NASCAR were calculated for each year from 2011 through 2015 and are shown in Fig. 11.

On average for the five years shown in Fig. 11, NASCAR race cars experienced a crash rate 134 times larger than passenger vehicles per mile. With NASCAR sub-injuries removed, on average, for the same five years passenger vehicle occupants experienced a 9.3 times larger injury rate, which includes injuries to driver and passenger vehicle occupants. While passenger vehicle fatality statistics are available during this comparison period, no driver fatalities were experienced during this time period in NASCAR. As shown in Fig. 11, NASCAR drivers experienced a lower injury rate than passenger vehicles, even when including the sub-injury data. This difference may be attributed to many factors including seat belt use and driver restraint system design.

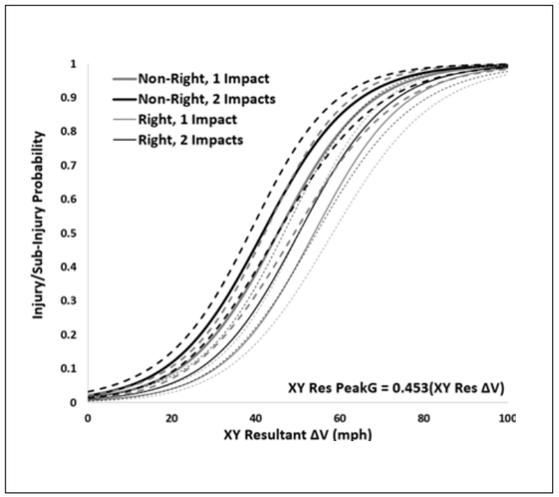


Fig. 6. AIS 1+ or Sub-Injury risk model with 95 % confidence intervals (dashed lines).

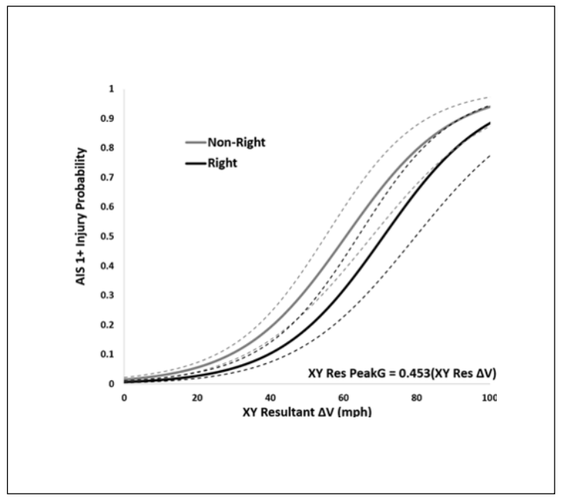


Fig. 7. AIS 1+ Injury risk model with 95 % confidence intervals (dashed lines).

4. DISCUSSION

Multiple logistic regression was used to estimate AIS 1+ injury only and AIS 1+ with sub-injury risk for motor sport drivers using motor sport-specific crash and medical record databases. As shown in Fig. 2, modelling of AIS 2+ injuries were not possible due to the limited occurrences of these more severe injuries. Model predictors were limited to processed IDR data and included XY Res ΔV,

“ DATASET REPRESENTS NASCAR RACE CAR CRASH CHRACTERISTICS AND DRIVER RESTRAINT PERFORMANCE ”

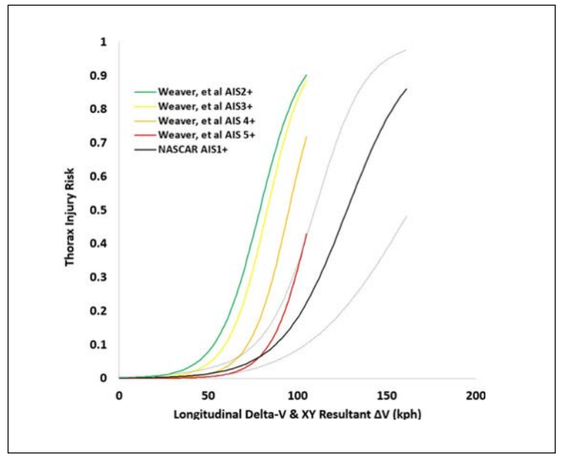


Fig. 8. Thorax injury risk models for belted frontal occupants with 95 % confidence intervals (dashed lines).

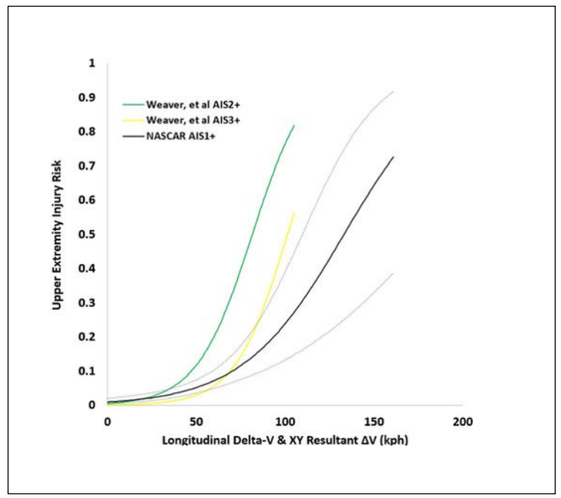


Fig. 9. Upper extremity injury risk models for belted frontal occupants with 95 % confidence intervals (dashed lines).

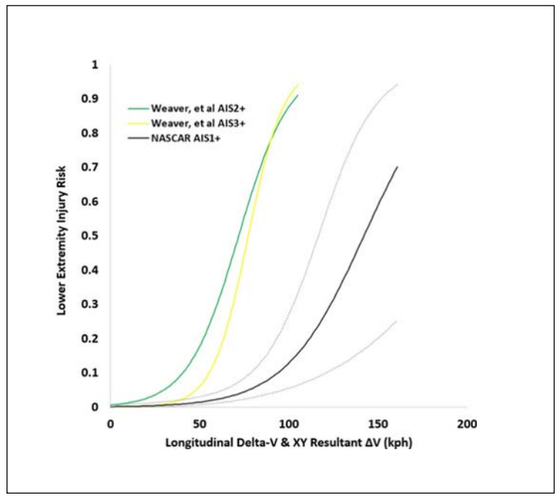


Fig. 10. Lower extremity injury risk models for belted frontal occupants with 95 % confidence intervals (dashed lines).

XY Res Peak G, the number of impacts during an event and the PDOF. Injury risk estimates were also generated for AIS body regions during frontal impacts where sufficient data allowed.

Injury risk estimates for the thorax, upper extremity and lower extremity were compared to models developed by Weaver, et al. For these models only frontal impacts were considered. This data subset consisted of 721 frontal cases of which 11, 29 and 10 contained AIS 1+ injuries for the thorax, upper extremity and lower extremity, respectively. The models compared with the belted Weaver, et al. models for each body region are shown in Figs. 8–10. The Weaver, et al. models were limited to 105 km per hour (kph) and used the longitudinal ΔV. In each of the three body regions, the NASCAR model estimates a lower injury risk for a lesser AIS severity where the risk is greater than 0.1. At less than 0.1 injury risk, the NASCAR AIS 1+ curve predicts higher injury prob- ability compared to the Weaver, et al. AIS 3+, AIS 4+ and AIS 5+ curves in thorax and upper extremity body regions.

NASCAR requires drivers to use a motor sport specific restraint system. One of components of this system is a head and neck restraint device meeting the SFI Foundation (SFI) 38.1 Head and Neck Restraint Systems specification. For initial head and neck restraint design vali- dation, two zero-degree frontal sled tests and one thirty degree right frontal oblique sled test are required by SFI 38.1. The sled tests use a 68 G peak acceleration and a 63 kph (39.1 mph) velocity change test pulse. The specification limits peak 50th percentile male Anthropomorphic Test Device (ATD) upper neck forces to ± 2500 N (562 lbf) from zero through 80 ms and ± 3200 N (719.4 lbf) from 80 to 120ms. Neck Injury Criteria (Nij) may not exceed 1.0 (SFI. SFI Foundation, Inc., 2015). The SFI 38.1 acceleration pulse has become a motor sport industry standard for assessing motor sport safety equipment beyond head and neck restraints. Applying Eq. (1) with inputs of 39.1 mph, 68 G, Right = 0 and number of impacts = 1 produces an AIS 1+ or Sub-Injury risk estimate of 0.83 (95 % CI [0.66, 0.92]). Applying Eq. (2) with the same predictor values produces an AIS 1+ injury risk of 0.78 (95 % CI [0.58, 0.89]). Reduced injury risk with increasing injury severity is consistent with Weaver, et al. findings for specific body region models.

Seat belt restraint use has consistently been shown to reduce injury risk. While nationwide passenger vehicle restraint use shows an in- creasing trend over the last decade there are still substantial numbers of occupants injured or killed who are unrestrained annually. Seat belt use in NASCAR is compulsory and tight seat belts are favoured by drivers due to improved feel and coupling with the vehicle. Prior to the start of a race, NASCAR drivers don their restraint systems, often with the help of an interior technician. There have been a few cases of motor sport drivers inadvertently releasing their seat belt restraint systems, typically while warming tires. Warming tires is a common prerace or caution period motion which consists of large alternating inputs to the steering wheel, necessitating the driver's hands to sweep past the seat belt re- lease mechanism located inferior to the navel. Following an inadvertent release, the driver has returned to pit road to redon the seat belt assembly. There are no documented cases of unrestrained NASCAR drivers involved in crashes.

> **"THERE ARE NO DOCUMENTED CASES OF UNRESTRAINED NASCAR DRIVERS INVOLVING CRASHES"**

Early coupling of occupants to the vehicle is a maxim of good occupant restraint (Hahum and Melvin, 2002). Passenger vehicle seat belt pretensioners increase the seat belt restraining forces earlier during a crash event. Motor sport seat belt restraint systems do not include crash activated seat belt pretensioners, as driver's manually pretension their restraint systems. Previous research has shown normal motor sport seat

belt pretensions to be 91.2 N (20.5 lbs) for shoulder belts and 110.3 N (24.8 lbs) for the lap belts (J. Patalak et al., 2018). Further, typical non- crash impacts which occur during normal racing make activation logic for such systems challenging. The NASCAR driver restraint system is also fully customized for each driver. Drivers are coupled to their all-belts-to-seat containment seats using custom molded foam inserts. These inserts must meet SFI 45.2 (SFI. SFI Foundation, Inc., 2013) and fill the void between the driver's body and the internal structure of the seat. The lateral head surround wings are lined with defined minimum thicknesses of SFI 45.2 foam and must be positioned at the appropriate height for each driver. Lateral leg support extensions, energy absorbing toe board foam and a knee knocker increase lower extremity protection.

While additional crash event information is available, such as driver age, medical history, restraint design and manufacturer, this study limited model inputs to IDR originated data. The purpose of this con- straint was to permit exploration for future use of the models for emergency response vehicle dispatch prioritization and IFCC driver triage applications. Previous research has identified advantages of Advanced Automatic Crash Notification (AACN) systems in passenger vehicles. The benefits of these automated post-crash passenger car systems can include reduced emergency responder dispatch/arrival times, reduced fatalities and improved trauma center transport decisions. During NASCAR National Series sanctioned events, emergency vehicle dispatch to on-scene arrival time is measured in seconds. Crash incidents have involved up to 25 vehicles simultaneously. While there are multiple emergency response vehicle units at each event, the models developed in this study could be used for additional input to emergency vehicle dispatch to aid in prioritization of available emergency medical resources.

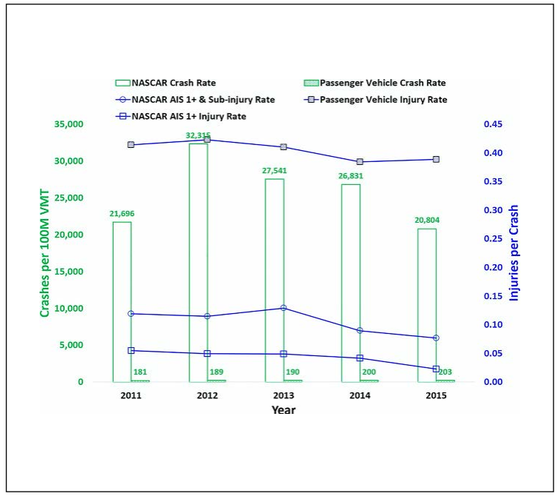


Fig. 11. Annual NASCAR & NHTSA Passenger Vehicle crash & injury rates.

5. LIMITATIONS

The IDR data in this study does not include pre-trigger threshold acceleration information, which slightly underestimates the actual ΔV of the crashes. In 2019, updated IDR firmware was deployed in the MENCS IDRs which captures the pre-trigger threshold data. Analysis of available 2019 MENCS IDR data with and without pre-trigger accel- eration show an average difference in ΔV of 3.5 kph (2.2 mph). Modeling of higher severity AIS injuries were not possible due to the limited occurrences of these injuries in the NASCAR data set. The po- tential for NASCAR drivers to withhold injury or sub-injury signs and symptoms from medical staff exists and only injury information collected in the IFCC or upon follow up is available and included in this study. While this limitation is difficult to quantify, no NASCAR driver has missed a subsequent race event due to an undisclosed previously incurred on-track crash related injury. The curve comparisons shown in Figs. 8–10 include the Weaver et al. models which used AIS version 98, while the NASCAR AIS is version 2005.

6. SUMMARY

Eight race seasons totaling more than 2000 crash incidents were processed and assessed to develop a relationship between crash char- acteristics and driver injury risk. 246 of the 2065 crash incidents contained a finding of sub-injury or AIS 1+ injury. Multiple logistic regression was used to develop estimates for sub-injury and AIS 1+ injury using crash attributes including delta-V, peak acceleration, principal direction of force and the number of impacts during an incident. Increasing resultant delta-V, resultant peak acceleration and the number of impacts during a crash event all increase estimated driver AIS 1+ injury and sub-injury risk for the Eq. (1) model. After accounting for the other predictors in the model, right lateral impacts were found to have a lower estimated injury risk than all other principal directions of force for Eq. 1 and 2 models. On average, for 2011 through 2015, full time NASCAR drivers experienced 134 times the crashes per mile than passenger vehicles, but experienced 9.3 times fewer injuries per crash. Thorax, upper and lower extremity body region specific models for frontal impacts estimate lower injury risk for NASCAR drivers than for passenger vehicles. Incorporation of this model into future vehicle IDR systems could serve as an additional input for emergency vehicle dispatch to aid in prioritization of available emergency medical resources during on-track crashes.

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DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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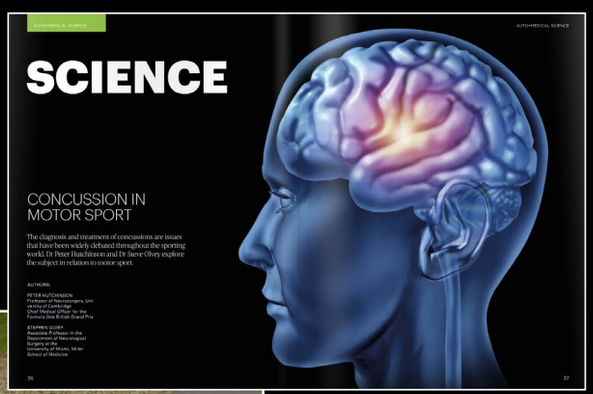

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